# Diversion head works

# Content…

Types- selection of the suitable site for the diversion headwork components of diversion headwork- Causes of failure of structure on

pervious foundation- Khosla's theory- Design of
concrete sloping glacis weir.

# Introduction…

- Any hydraulic structure which supplies water to
  the off-taking canal is called a headwork.

Headwork may be divided into two

1. Storage headwork.
2. Diversion headwork.

# Storage head works

- Dam is constructed across a river valley to form storage reservoir, known as storage head works.
- Water is supplied to the canal from this reservoir through canal regulator.
- These serves for multipurpose function like hydro- electric power generation, flood control, fishery.

# Diversion head works

- Weir or barrage is constructed across a perennial river to raise water level and to divert  the water to canal, is known as diversion head  work.

- Flow of water in the canal is controlled by  canal head regulator.

# Objective of diversion head work

- It raises the water level on its upstream side.
- It regulates the supply of water into canals.
- It controls the entry of silt into canals
- It creates a small pond (not reservoir) on its
upstream and provides some pondage.
- It helps in controlling the fluctuation of water level in river during different

# Site selection for diversion head work

- The river section at the site should be narrow
  and well-defined.
- The river should have high, well-defined, in  erodible and non-submersible banks so that the  cost of river training works is minimum.
- The canals taking off from the diversion head  works should be quite economical and
- Should have a large commanded area.

- There should be suitable arrangement for the diversion of river during construction.

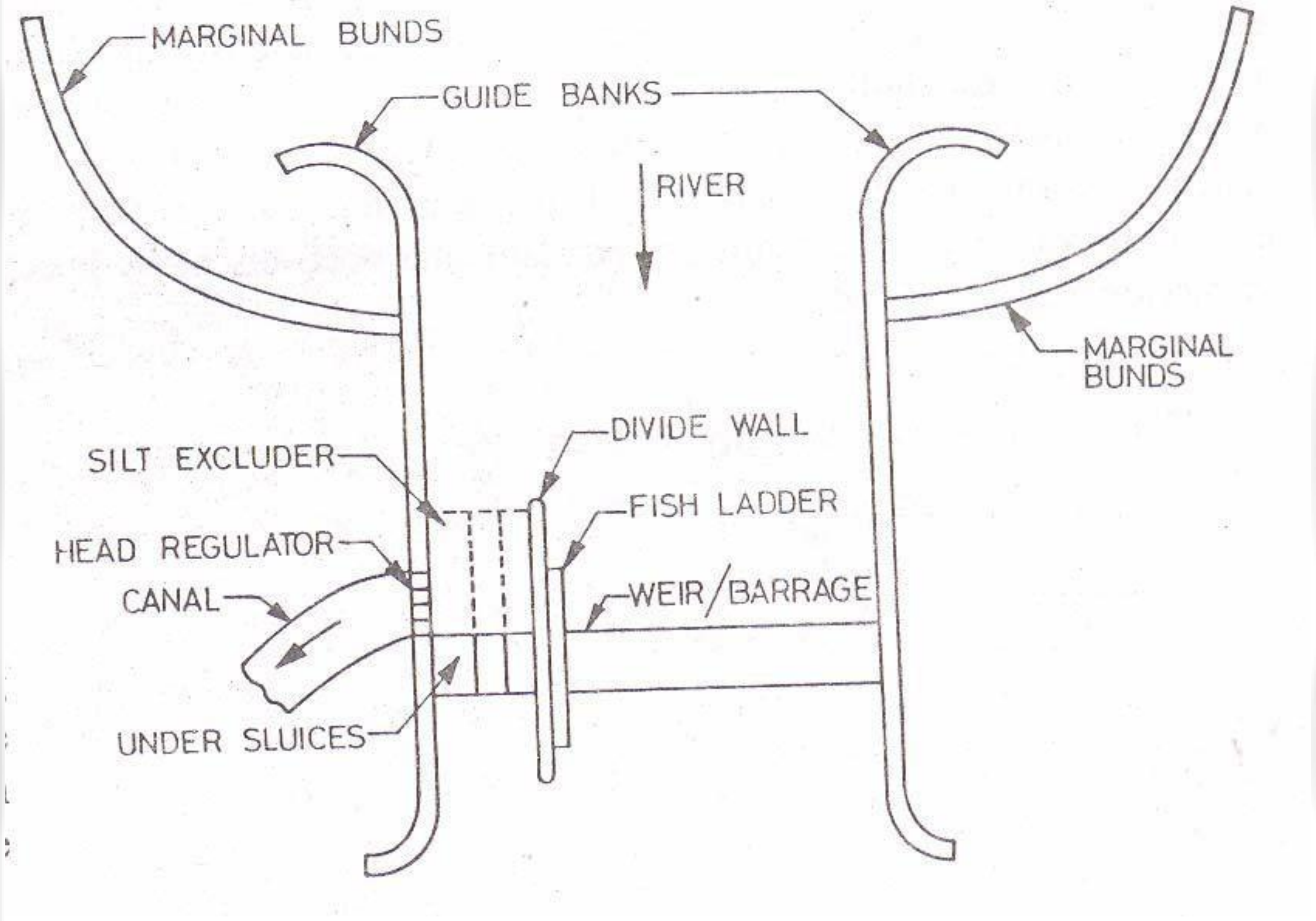
- The site should be such that the weir (or barrage) can be aligned at right angles to the direction of flow in the river.

- There should be suitable locations for the under sluices, head regulator and other components of the diversion

- The diversion head works should not submerge costly land and property on its upstream.
- Good foundation should be available at the site.
- The required materials of construction should be available near the site.
- The site should be easily accessible by road or rail.
- The overall cost of the project should

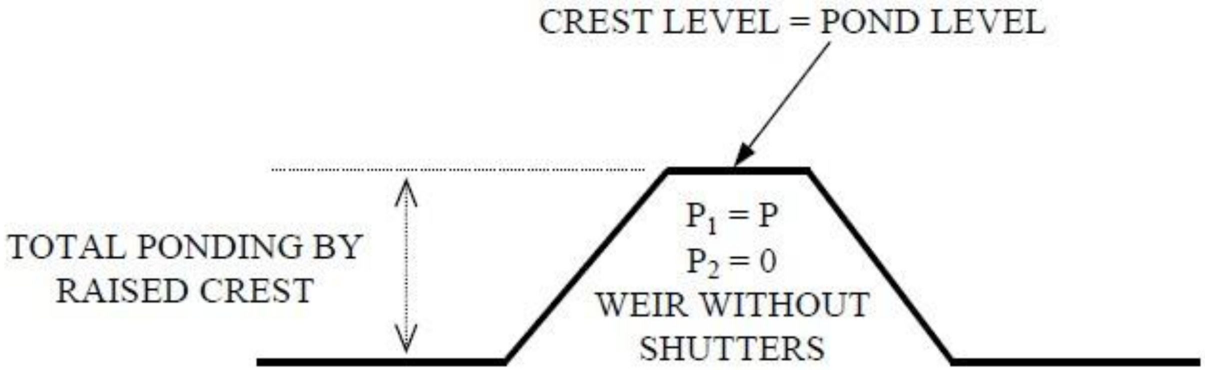
# Components of a diversion headwork

- Weir or barrage
- Undersluices
- Divide wall
- Fish ladder
- Canal head regulator
- Silt excluders/ Silt prevention devices
- River training works (Marginal bunds and guide banks)

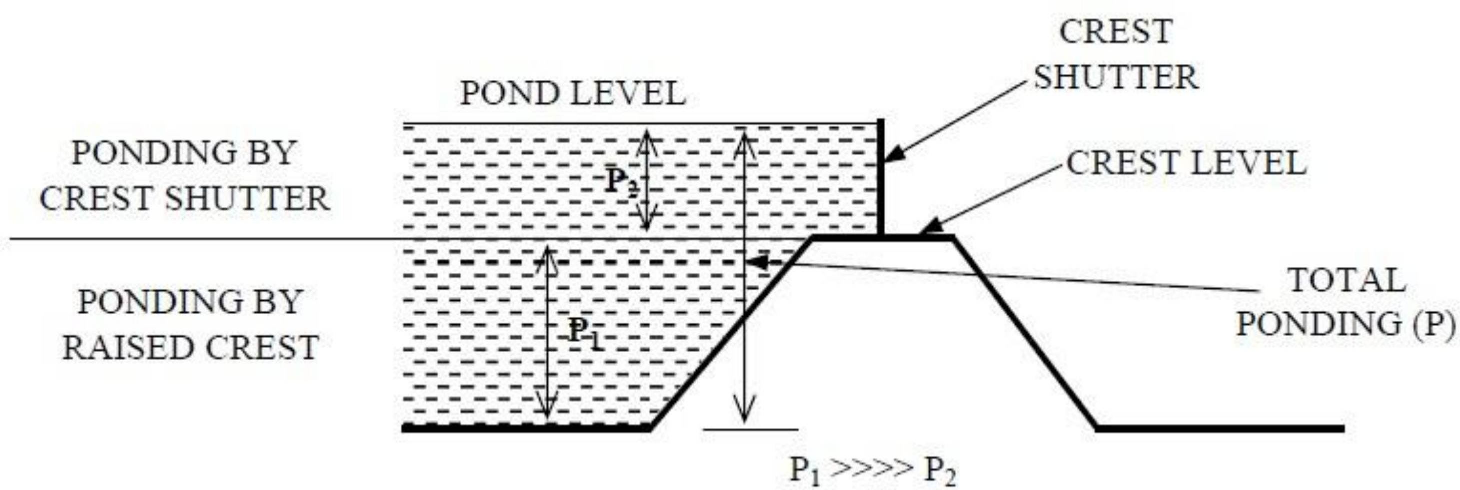

MARGINAL BUNDS
GUIDE BANKS
RIVER
MARGINAL
BUNDS
DIVIDE WALL
SILT EXCLUDER
FISH LADDER
HEAD REGULATOR
CANAL
WEIR/BARRAGE
UNDER SLUICES

# Weir

- Normally the water level of any perennial river is such that it cannot be diverted to the irrigation canal.
- The bed level of the canal may be higher than the existing water level of the river.
- In such cases weir is constructed across the river to raise the water level.
- Surplus water pass over the crest of weir.
- Adjustable shutters are provided on the crest to raise
  the water level to some required height.




(a) Fig: Weir without shutters

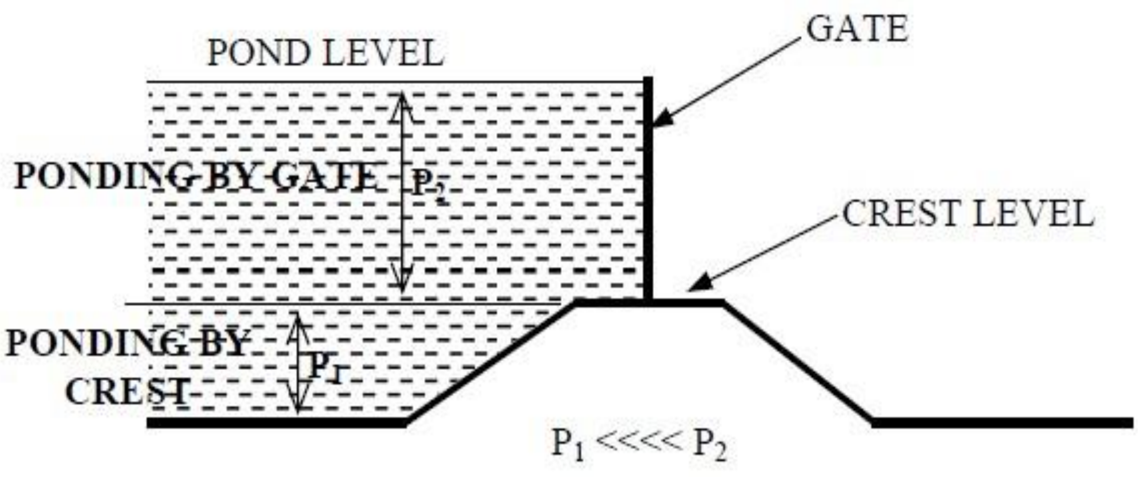



(b) Fig: Weir with shutters

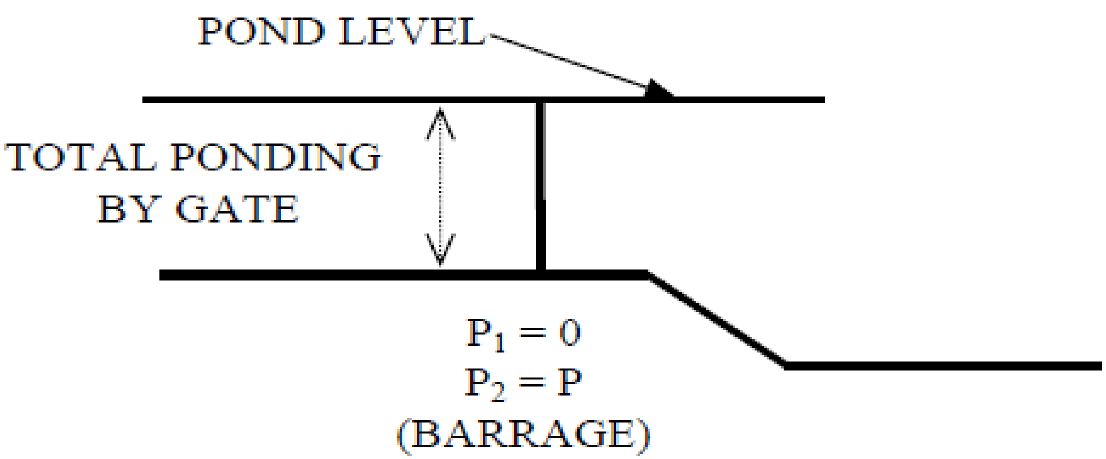
# Barrage

- When the water level on the up stream side of the weir is required to be raised to different levels at different time, barrage is constructed.

- Barrage is an arrangement of adjustable gates
or shutters at different tires over the weir.




(c) Fig: Barrage with a small raised crest




(d) Fig: Barrage without any raised crest

| Barrage | Weir |
| --- | --- |
| Low set crest | High set crest |
| Ponding is done by means of gates | Ponding is done against the raised crest or partly against crest and partly by shutters |
| Gated over entire length | Shutters in part length |
| Gates are of greater height | Shutters are of smaller height, 2 m |
| Perfect control on river flow | No control of river in low floods |
| High floods can be passed with minimum afflux | Excessive afflux in high floods |
| Less silting upstream due to low set crest | Raised crest causes silting upstream |
| Longer construction period | Shorter construction period |
| Silt removal is done through under sluices | No means for silt disposal |
| Costly structure | Relatively cheaper structure |

# Under sluices

- Also known as scouring sluices.
- The under sluices are the openings provided
  at the base of the weir or barrage.
- These openings are provided with adjustable gates. Normally, the gates are kept closed.
- The suspended silt goes on depositing in front
  of the canal head regulator

- When the silt deposition becomes appreciable  the gates are opened and the deposited silt is  loosened with an agitator mounting on a boat.

- The muddy water flows towards the downstream through the scouring sluices.

- The gates are then closed. But, at the period
of flood, the gates are kept opened

# Divide wall

- The divide wall is a long wall constructed at right angles in the weir or barrage, it may be constructed with stone masonry or cement concrete.
- On the upstream side, the wall is extended just to cover the canal head regulator and on the downstream side, it is extended up to the launching apron.

*The functions of the divide wall are as follows:*

- To form a still water pocket in front of the canal head so that the suspended silt can be settled down which then later be cleaned through the scouring sluices from time to time.
- It controls the eddy current or cross current in front of the canal head.
- It provides a straight approach in front of the canal head.
- It resists the overturning effect on the weir or barrage caused by the pressure of the impounding water

# Fish ladder

- The fish ladder is provided just by the side of the divide wall for the free movement of fishes.
- Rivers are important source of fishes.
- The tendency of fish is to move from upstream to downstream in winters and from downstream to upstream in monsoons.
- This movement is essential for their survival.
- Due to construction of weir or barrage, this movement gets obstructed, and is detrimental to the fishes.

- In the fish ladder, the fable walls are constructed in a zigzag manner so that the velocity of flow within the ladder does not exceed 3 m/sec.
- The width, length and height of the fish ladder depend on ... and the type of the ...

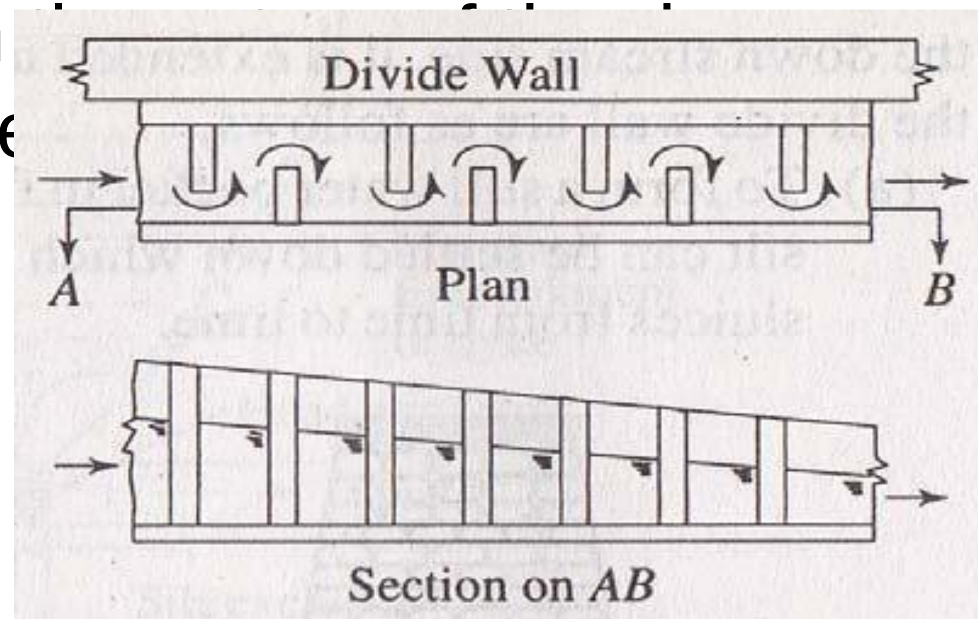



Fig: Fish Ladder

# Canal head regulator

- A structure which is constructed at the head of the canal to regulate flow of water is known as canal head regulator.
- It consists of a number of piers which divide the total width of the canal into a number of spans which are known as bays.
- The piers consist of number tiers on which the adjustable gates are placed.

- The gates are operated form the top by suitable mechanical device.

- A platform is provided on the top of the piers for the facility of operating the gates.

- Again some piers are constructed on the down stream side of the canal head to support the roadway.

## ***Functions of Canal Head Regulator***

- It regulates the supply of water entering the canal
- It controls the entry of silt in the canal
- It prevents the river-floods from entering the canal

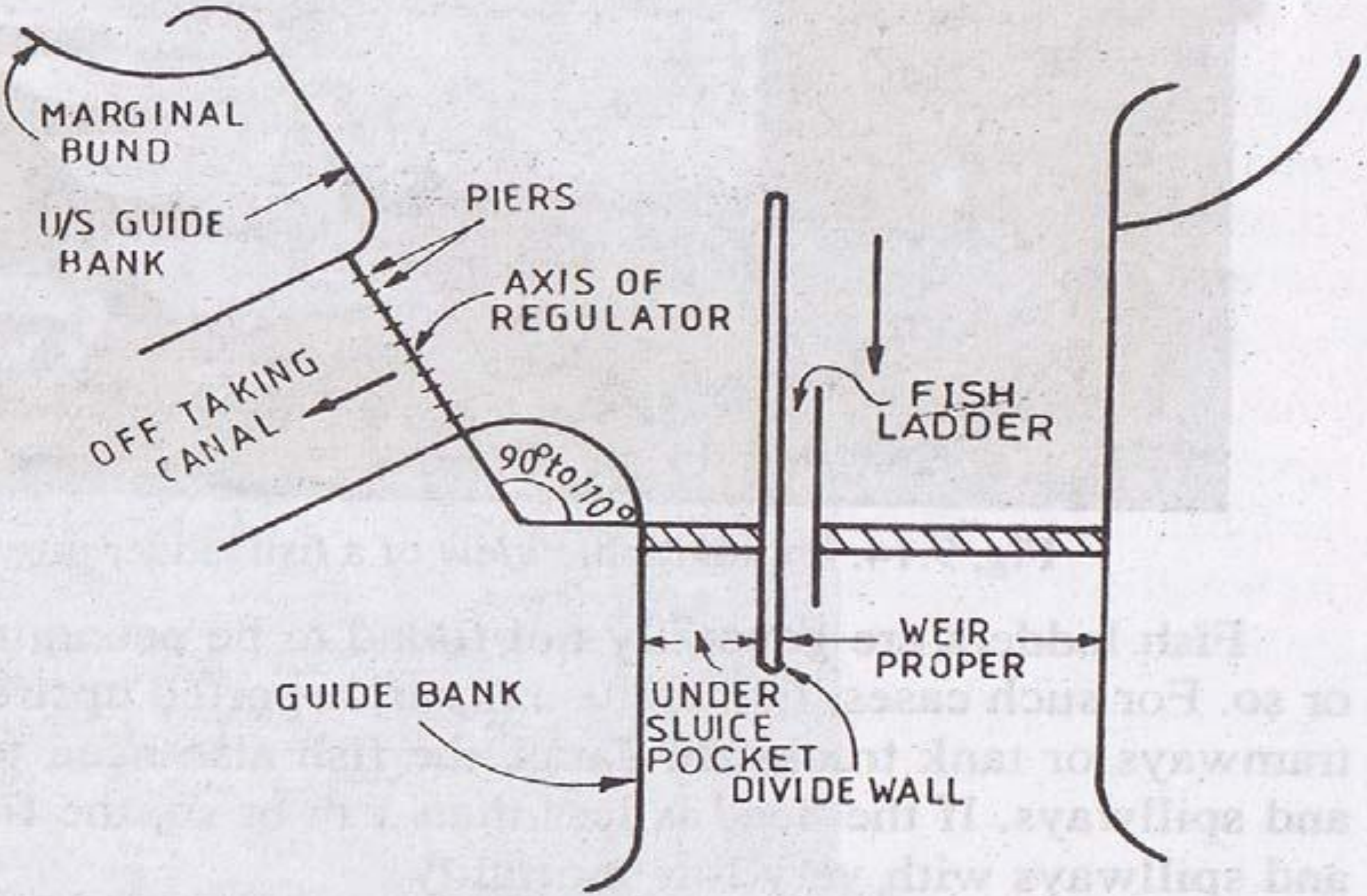



**Fig: Alignment of a canal head regulator**

# Silt regulation works

- 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 Excluders
  - (b) Silt Ejectors

## Silt Excluders

- Silt excluders are those works which are constructed on the bed of the river, upstream of  the head regulator.
- The clearer water enters the head regulator
and silted water enters the silt excluder.
- In this type of works, the silt is, therefore,,  removed from the water before in enters the  canal.

## Silt Ejectors

- Silt ejectors, also called silt extractors, are those devices which extract the silt from the canal water after the silted water has travelled a certain distance in the off-take canal.

- These works are, therefore, constructed on the bed of the canal, and little distance downstream from the head regulator.

# River training works

- River training works are required near the weir site in order to ensure a smooth and an axial flow of water, and thus, to prevent the river from outflanking the works due to a change in its course.
- *The river training works required on a canal headwork are:*
  - (a) Guide banks
  - (b) Marginal bunds
  - (c) Spurs or groynes

## Guide Bank

- When a barrage is constructed across a river which
  flows through the alluvial soil, the guide banks must
- be constructed on both the approaches to protect the structure from erosion.

*Guide bank serves the following purposes:*

- It protects the barrage from the effect of scouring and erosion.
- It provides a straight approach towards the barrage.
- It controls the tendency of changing the course of the river

## Marginal Bunds

- The marginal bunds are earthen embankments which are constructed parallel to the river bank on one or
- both the banks according to the condition. The top width is generally 3 m to 4 m. The side slope on the
- river side is generally 1.5: 1 and that on the

  country side is 2:1.

- *The marginal bunds serve the following purposes:*
  - It prevents the flood water or storage water from entering the surrounding area which may be submerged or may be water logged.
  - It retains the flood water or storage water within a specified section.
  - It protects the towns and villages from devastation during the heavy flood.
  - It protects valuable agricultural lands.

# Causes of failure of structure

- Irrigation structures (or hydraulic structures) for the diversion and distribution works are weirs, barrages, head regulators, distributary head regulators, cross regulators, cross-drainage works, etc.

- These structures are generally founded on
alluvial soils which are highly pervious.

- These soils are easily scoured when the high velocity water passes over the structures.
- The failures of weirs constructed on the permeable foundation may occur due to various causes, which may be broadly classified into the following two categories:

1. Failure due to- subsurface flow
2. Failure due to surface flow

# 1. Failure due to- subsurface flow

## (a) Failure by Piping or undermining

- water from the upstream side continuously percolates through the bottom of the foundation and emerges at the downstream end of the weir or barrage floor.
- The force of percolating water removes the soil particles by scouring at the point of emergence.
- As the process of removal of soil particles goes on continuously, a depression is formed which extends backwards towards the upstream through the bottom of the

- A hollow pipe like formation thus develops under the foundation due to which the weir or barrage may fail by subsiding.
- This phenomenon is known as failure by piping or undermining.

## (b) Failure by Direct uplift

- The percolating water exerts an upward pressure on the foundation of the weir or barrage.
- If this uplift pressure is not counterbalanced by the self weight of the structure, it may fail by rapture.

# 2. Failure due to- surface flow

<u>(a) By hydraulic jump</u>

- When the water flows with a very high velocity  over the crest of the weir or over the gates of  the barrage, then hydraulic jump develops.
- This hydraulic jump causes a suction pressure  or negative pressure on the downstream side  which acts in the direction uplift pressure.
- If the thickness of the impervious floor is  sufficient  then the structure fails by

(b) By scouring

- During floods, the gates of the barrage are kept
  open and the water flows with high velocity.
- The water may also flow with very high velocity over the crest of the weir.
- Both the cases can result in scouring effect on the downstream and on the upstream side of the structure.
- Due to scouring of the soil on both sides of the structure, its stability gets

# Design aspects

(a)<u>Subsurface flow</u>

1. The structure should be designed such that the piping failure does not occur due to subsurface flow.
2. The downstream pile must be provided to reduce the exit gradient and to prevent piping.
3. An impervious floor of adequate length is provided to increase the path of percolation and to reduce the hydraulic gradient and the seepage force.

4. The seepage path is increased by providing piles and impervious floor to reduce the uplift pressure.
5. The thickness of the floor should be sufficient to resist the uplift pressure due to subsurface flow.
6. A suitably graded inverted filter should be provided at the downstream end of the impervious floor to check the migration of soil particles along with water. The filter layer is loaded with concrete blocks.

## (b) Surface flow

1. The piles (or cut-off walls) at the upstream and downstream ends of the impervious floor should be provided upto the maximum scour level to protect the main structure against scour.
2. The launching aprons should be provided at the upstream and downstream ends to provide a cover to the main structure against scour.
3. A device is required at the downstream to dissipate energy. For

4. Additional thickness of the impervious floor is provided at the point where the hydraulic jump is formed to counterbalance the suction pressure.
5. The floor is constructed as a monolithic structure to develop bending resistance (or beam action) to resist the suction pressure.

# Khosla’s theory

- Many of the important hydraulic structures, such as weirs and barrage, were designed on the basis of
- Bligh’s theory between the periods 1910 to 1925.
- In 1926 – 27, the upper Chenab canal siphons, designed on Bligh’s theory, started posing undermining troubles.
- Investigations started, which ultimately lead to Khosla’s theory.

Following are some of the main points from Khosla's Theory.

1. Outer faces of end sheet piles were much more effective than the inner ones and the horizontal length of the floor.
2. Intermediated piles of smaller length were ineffective except for local redistribution of pressure.
3. Undermining of floor started from tail end.

4. It was absolutely essential to have a reasonably deep vertical cut off at the downstream end to prevent undermining.
5. Khosla and his associates took into account the flow pattern below the impermeable base of hydraulic structure to calculate uplift pressure and exit gradient.
6. Seeping water below a hydraulic structure does not follow the bottom profile of the impervious floor as stated by Bligh but each particle traces its path along a

## Method of independent variable

- Most designs do not confirm to elementary profiles (specific cases).
- In actual cases we may have a number of piles at upstream level, downstream level and intermediate points and the floor also has some thickness.
- Khosla solved the actual problem by an empirical method known as method of independent variables.

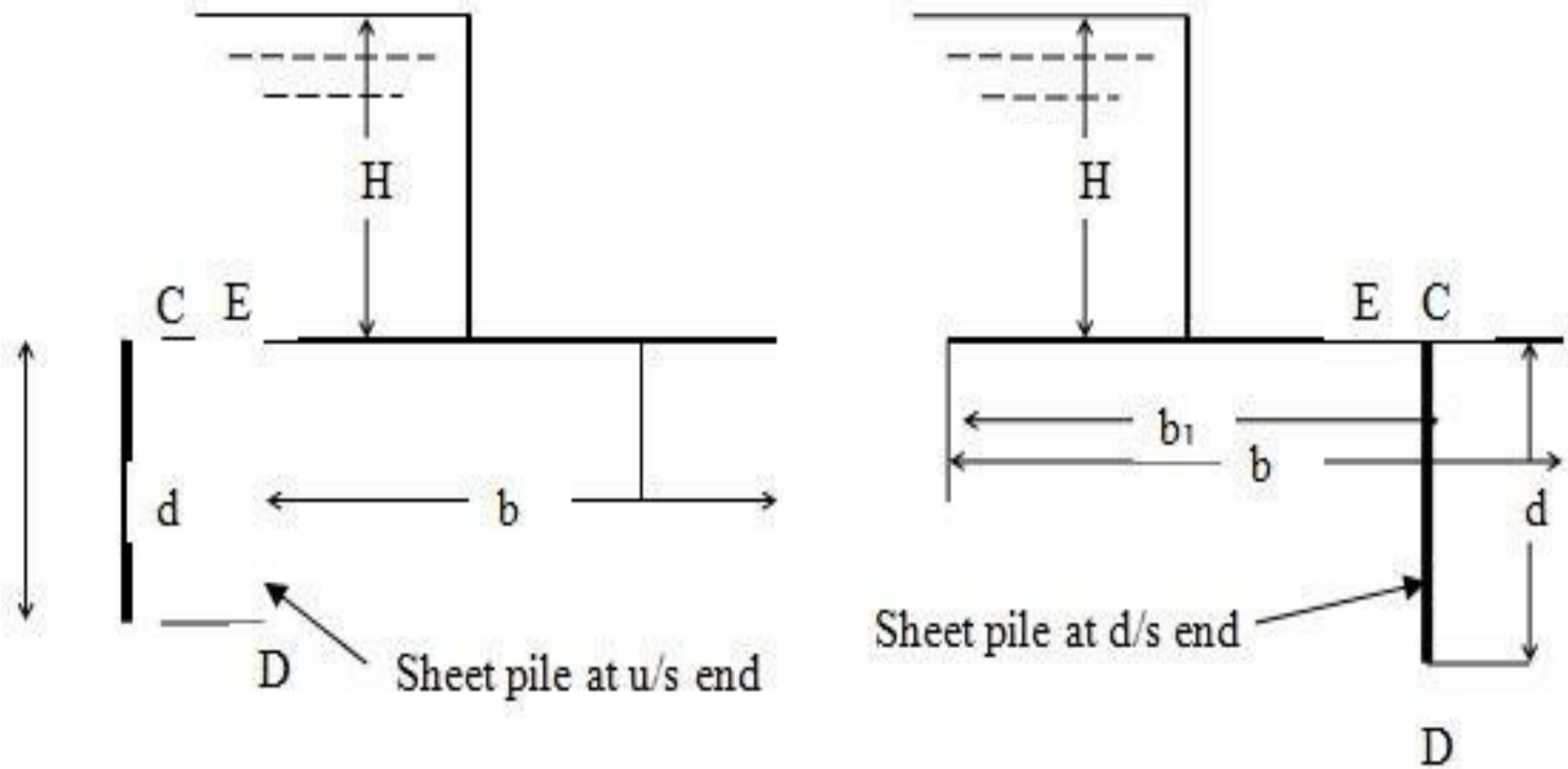
- This method consists of breaking up a complex profile into a number of simple profiles, each of which is independently amiable to mathematical treatment.
- Then apply corrections due to thickness of slope of floor.
- As an example the complex profile shown in fig is broken up to the following simple profile and the pressure at Key Points obtained.

- Straight floor of negligible thickness with pile at upstream ends.
- Straight floor of negligible thickness with pile at
downstream end.
- Straight floor of negligible thickness with pile at intermediate points.
- The pressure is obtained at the key points by considering the simple profile.

- For the determination of seepage below the foundation of hydraulic structure developed the method of independent variable.
- In this method, the actual profile of a weir which is complex, is divided into a number simple profiles, each of which cab be solved mathematically without much difficulty.
- The most useful profile considered are:

(i)A straight horizontal floor of negligible thickness provided with a sheet pile at the upstream end or a sheet pile at the downstream end.

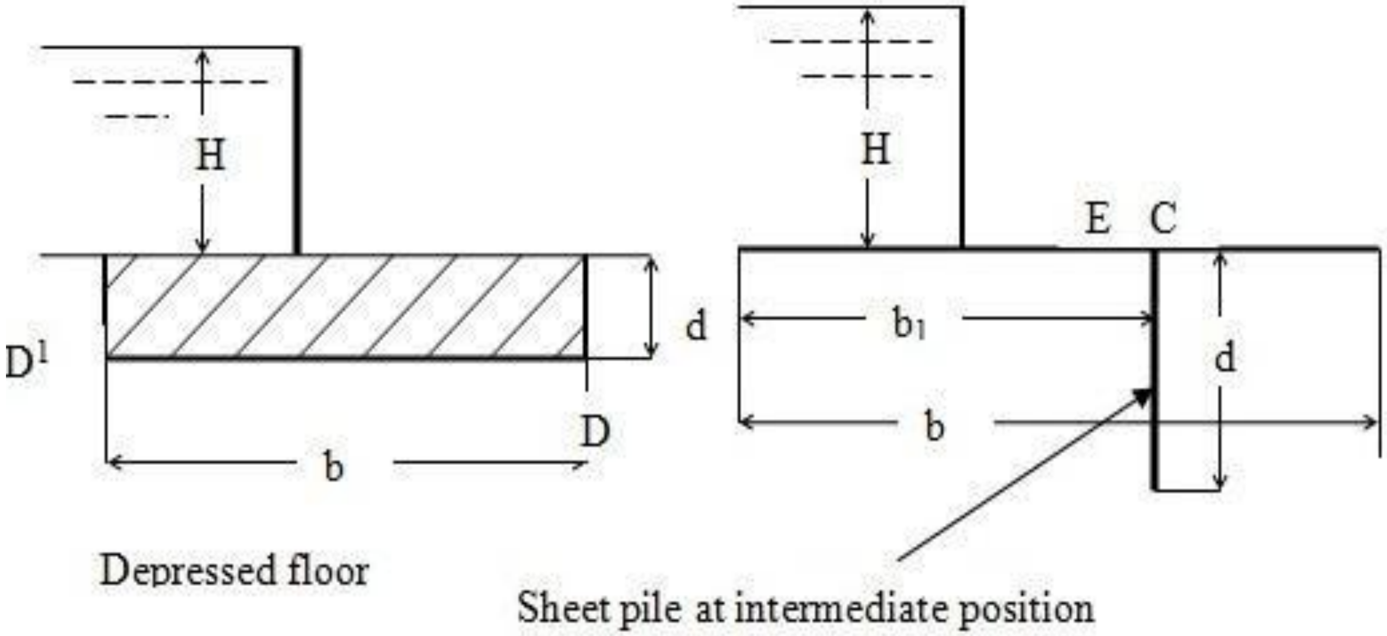
(ii) A straight horizontal floor depressed below the



H
C
E
d
b
D
Sheet pile at u/s end
H
E
C
b1
b
d
Sheet pile at d/s end
D

# Intermediate point

- The mathematical solution of the flow-nets of the above profiles have been given in the form of curves.
- From the curves, percentage pressures at various key points E, C be determined. The important points to note are:
- Junctions of pile with the floor on either side{E, C (bottom), E1, C1 (top) }
- Bottom point of the pile (D), and
- Junction of the bottom corners (D, D') in case of depressed floor




- The percentage pressures at the key points of a simple forms will become valid for any complex profile, provided the following corrections are effected:
  - correction for mutual interference of piles
  - correction for the thickness of floor
  - correction for slope of the floor.

## Correction for Mutual Interference of Piles

- Let b1 = distance between the two piles 1 and
  2, and
- D = the depth of the pile line (2), the influence of which on the neighbouring pile (1) of depth d must be determined
- b = total length of the impervious floor
- c = correction due to interference.

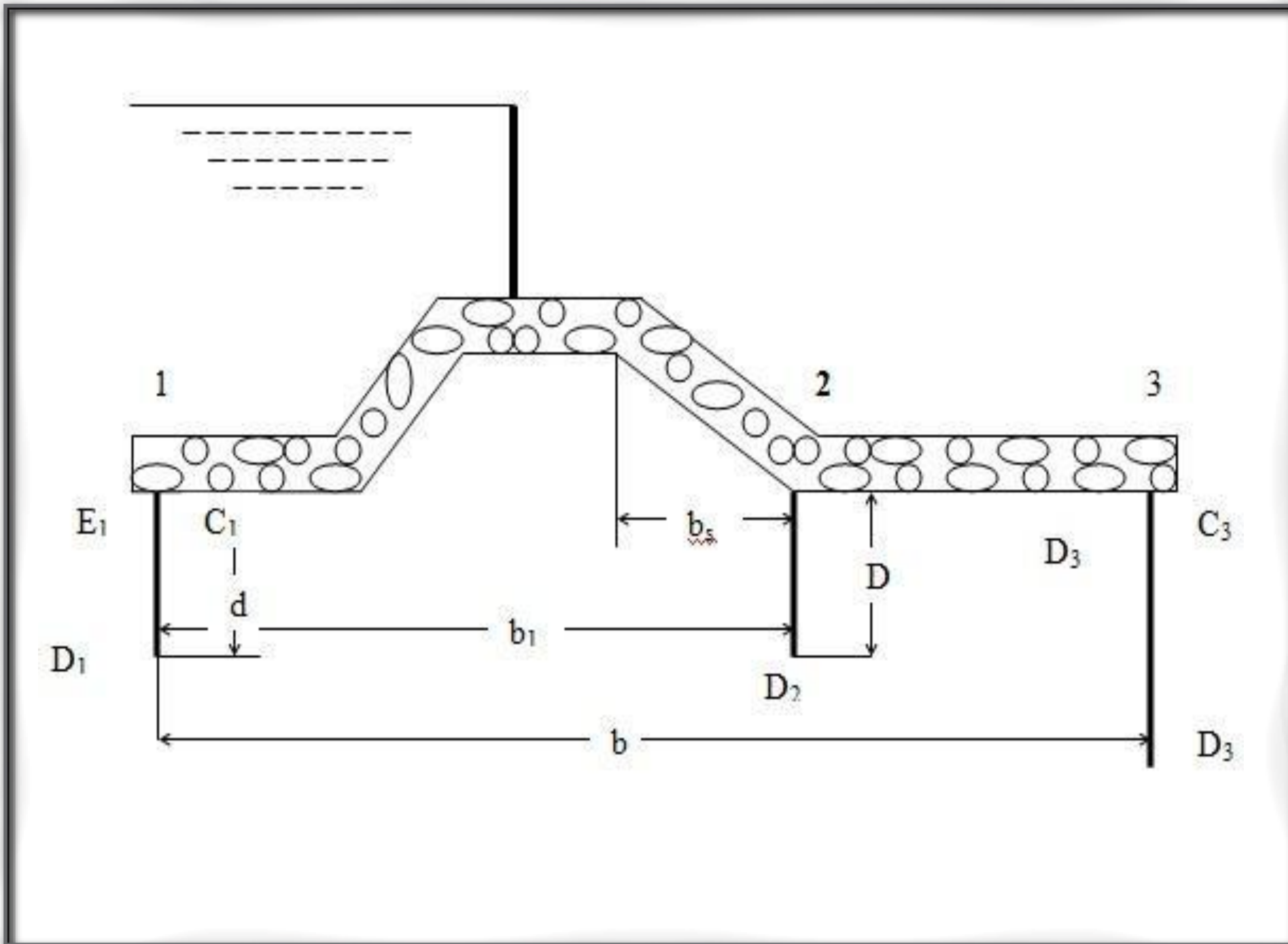
- The correction is applied as a percentage of the head

$$C = 19\sqrt{\frac{D}{b_1}}x\left(\frac{d+D}{b}\right)$$

This correction is positive when the point is considered to be at the rear of the interfering pile and negative for points considered in the forward or flow direction with the interfering pile.

## Correction for Floor Thickness

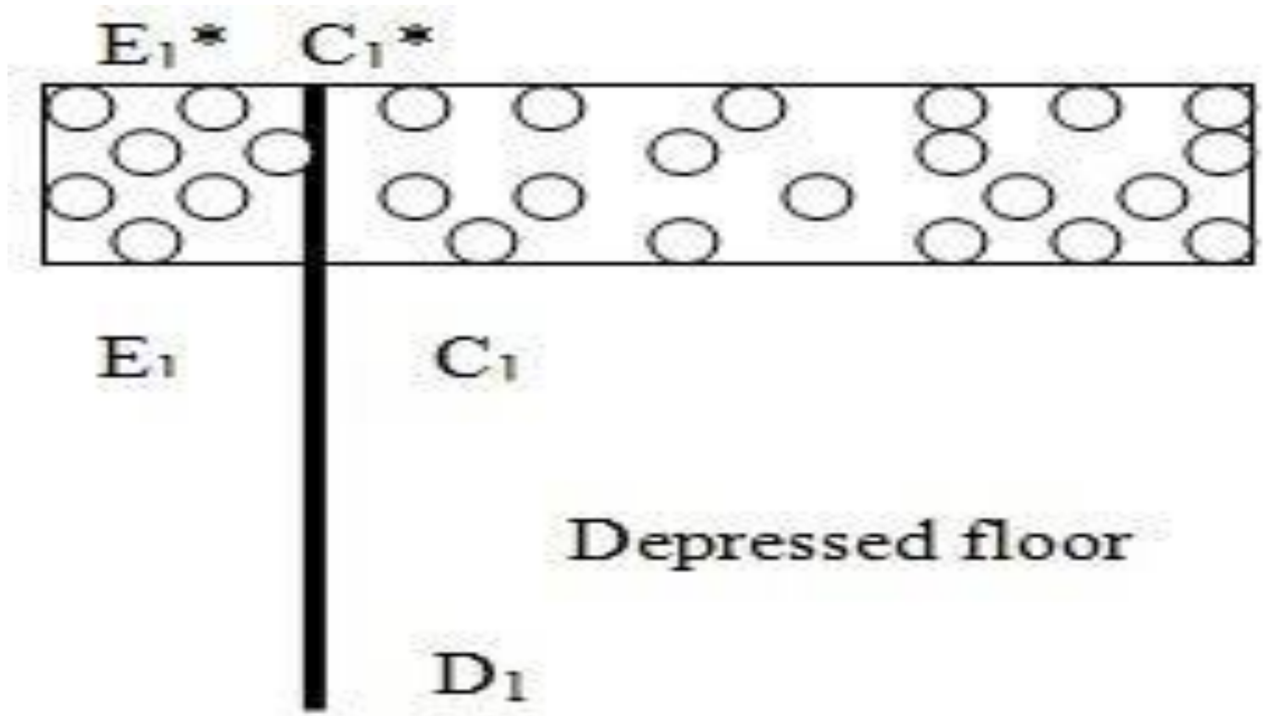
- Standard profiles assuming the floors as having negligible thickness.
- Hence the values of the percentage pressures computed from the curves corresponds to the top levels (E1*, C1*) of the floor.
- However, the junction points of the floor and pile are at the bottom of the floor (E1, C1)



1
2
3
$E_1$
$C_1$
$b_5$
$C_3$
$D_3$
D
d
$b_1$
$D_1$
$D_2$
b
$D_3$

- The pressures at the actual points E1 and C1 are interpolated by assuming a straight line variation in pressures from the points E1* to D1 and from D1 to C1.

- The corrected pressures at E1 should be less than the computed pressure t E1*. Therefore the correction for the pressure at E1 will be negative. And so also is for pressure at C1.


E1*
C1*
E1
C1
Depressed floor
D1

## Correction for Slope of Floor

- A correction for a sloping impervious floor is positive for the down slope in the flow direction and negative for the up slope in the direction of flow.
- The correction factor must be multiplied by the horizontal length of the slope and divided by the distance between the two poles between which the sloping floor exists.

| Slope (H : V) | Correction Factor |
|---|---|
| 1 : 1 | 11.2 |
| 2 : 1 | 6.5 |
| 3 : 1 | 4.5 |
| 4 : 1 | 3.3 |
| 5 : 1 | 2.8 |
| 6 : 1 | 2.5 |
| 7 : 1 | 2.3 |
| 8 : 1 | 2.0 |

# Exit gradient ($G_E$)

- It has been determined that for a standard form consisting of a floor length (b) with a vertical cut-off of depth (d), the exit gradient at its downstream end is g

$$G_E = \frac{H}{d} \times \frac{1}{\pi\sqrt{\lambda}}$$

Where, $\lambda = \frac{1+\sqrt{1+\alpha^2}}{2}$

$\alpha = b/d$

H = Maximum Seepage Head

Values of safe exit gradient may be taken as:

0.14 to 0.17 for fine sand

0.17 to 0.20 for coarse sand

0.20 to 0.25 for shingle