#132, AECS Layout, IT Park Road, Kundalahalli, Bangalore – 560 037 T:+9180 28524466 / 77

CMR
INSTITUTE
OF TECHNOLOGY

Department of Civil Engineering

## 17CV832 – HYDRAULIC STRUCTURES

Scheme and Evaluation

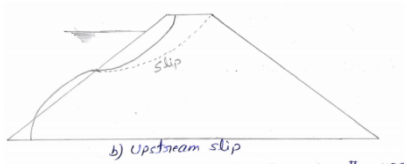
| Q.No. | Question | Mark | CO | PO | RBL |
|---|---|---|---|---|---|
| **1a** | What are earthen dams? Mention the advantages of earthen dams | **5** | **CO2** | **PO1** | **L1** |
| Ans | An embankment dam is a large artificial dam. It is typically created by the placement and compaction of a complex semi-plastic mound of various compositions of soil, sand, clay, or rock. Embankment dams come in two types: the earth-filled dam (also called an earthen dam or terrain dam) made of compacted earth, and the rock-filled dam.<br>Advantages:<br>• Design procedures are straight and easy<br>• Local natural materials are used<br>• Comparatively small establishment and equipment are required<br>• They resist settlement and movement better than rigid structures and cab is more stable for areas where earth movements are common. | | | | 5 |
| **1b** | A flow net is plotted for a homogeneous earthen dam of height 22m and free board 2m. The results obtained are, number of potential lines = 10; number of flow channels = 4. The dam has a horizontal filter of 30m length at the downstream end and the coefficient of permeability of the dam material is $5\times10^{-4}$ cm/sec. calculate the discharge per m run of the dam. | **5** | **CO2** | **PO2** | **L2** |
| Ans | The discharge through a dam section is approximately given by the equation<br>$q = K.\ H.\ \frac{N_f}{N_d}$<br>Where K = $5\times 10^{-4}$<br>H = 22 – 2 = 20m<br>$N_f$ = 4<br>$N_d$ = 10<br>Therefore, **q = 4 × $10^{-6}$ cumecs/m run of dam** | | | | 5M |
| 2. | What are the causes of failure in earthen dam? Explain them with relevant sketches | **10** | **CO2** | **PO1** | **L2** |
| Ans | Causes of failure of earth dams: 1. Hydraulic Failure 2. Seepage Failure 3. Structural Failure<br>**Hydraulic Failure**:<br>1. Overtopping of dams: Over topping failures result from the erosive action of water on the embankment. Erosion is due to un-controlled flow of water over, around, and adjacent to the dam. Earth embankments are not designed to be | | | | 1<br>Any |

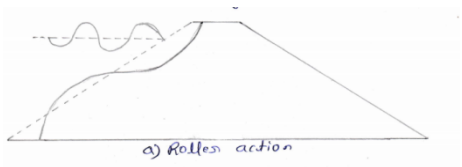
over-topped and therefore are particularly susceptible to erosion.

2

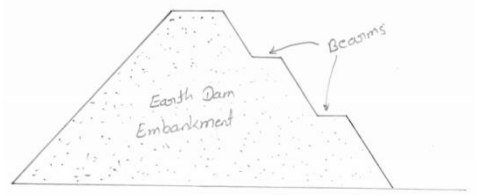
(3M)

2. Erosion of the Upstream Surface: the waves developed near the top surface due to the winds, try to notch out the sol from the upstream face and causes slip of u/s slope.



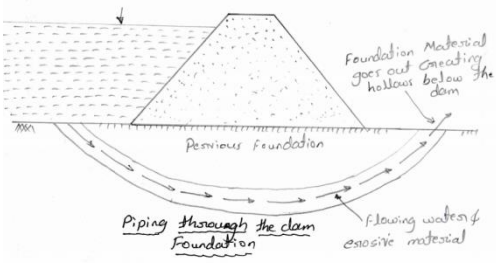

3. Erosion of the Downstream Surface: Due to rainfall, snow and winds the downstream surface of the dam also erodes. By providing a section of coarse materials here, this erosion can be reduced or prevented.

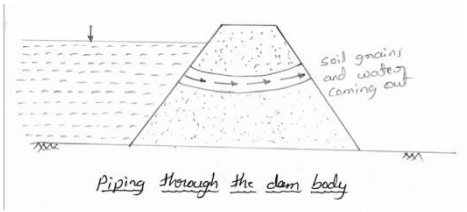



4. Erosion of the Downstream toe:
This can take place due to erosion of cross currents that may come from spillway buckets and erosion due to tail water.

(3M)

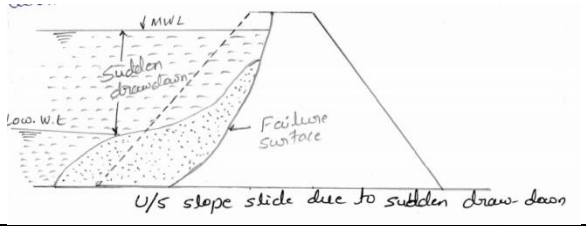
**Seepage Failure**: Seepage failure of the dams is of the following types
1. Piping through the dam and its foundation: If the seepage force exceeds the weight of the material the water washes away the soil from the plate and creates a hole in the ground. This hole deepens as more and more mateial is taken away from it and extends longitudinally, making a pipe hole called "Piping in the dam"




**Structural Failure:**
Failure of upstream face during sudden draw down
Failure due to sliding of foundation
damage due to burrowing animals
Failure of dam due to earthquake

Any
2
(3M)



| | | | | | |
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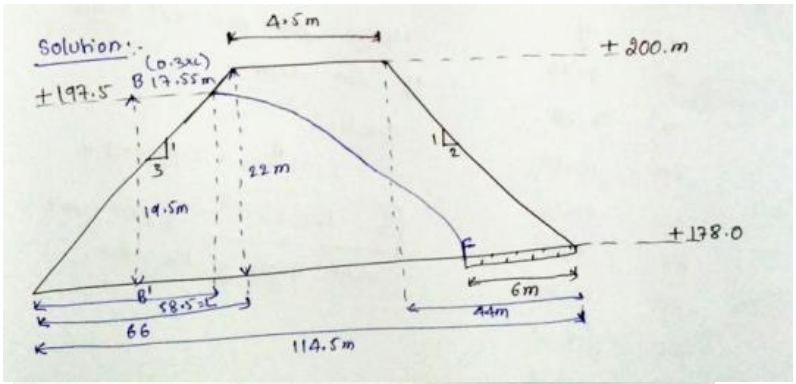
| 3. | **An earthen dam made of a homogeneous material has the following data:**<br>**Coefficient of permeability = $5\times10^{-4}$ cm/sec**<br>**Level of top of dam = 200.0m**<br>**Level of deepest river bed = 178.0m**<br>**H.F.L of reservoir = 197.5m**<br>**Width of top of dam = 4.5m**<br>**Upstream slope = 3:1**<br>**Downstream slope = 2:1**<br>**Determine the phreatic line for this dam section and the discharge passing through dam, if a horizontal filter of 6m is provided inward from the downstream to the dam** | **10** | **CO2** | **PO2** | **L3** |
| Ans |  <br>Equation of parabola (phreatic line<br>$y = \sqrt{2sx + s^2}$<br>$x = FB' = 114.5 - 6 - 58.5 + 17.55$<br>$x = 67.55m$<br>$y = BB' = 19.5m$<br>$s = \sqrt{x^2+y^2} - x = \sqrt{67.55^2 + 19.5^2} - 67.55$<br>$s = 2.76m$<br>∴ Equation of parabola<br>$y = \sqrt{5.52x + 7.62}$<br>The co-ordinates of parabola are tabulated bellow<br>x y<br>0 2.76<br>10 7.92<br>20 10.86<br>30 13.16<br>40 15.11<br>50 16.84<br>60 18.40<br>67.55 19.5<br>Seepage flow per unit length of the dam<br>$q = K.S$<br>$= 5\times10^{-6}$ m/s $\times$ 2.76m $\times$ 1m<br>$q = 0.138\times10^{-6}$ m³/s per unit metre length of the dam. | | | | 10M |

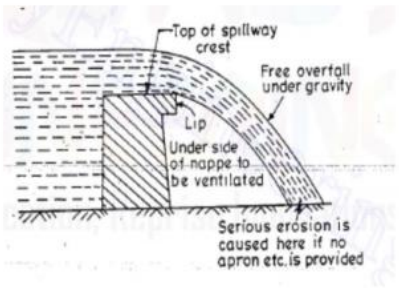
| 4. | **What is spillway? Explain a) Free fall spillway b) Ogee spillway c) Chute spillway d) Syphon spillway** | **10** | **CO3** | **PO3** | **L2** |
|---|---|---|---|---|---|

Ans

Spillway is the overflow portion of dam, over which surplus discharge flows from the reservoir to the downstream. It is a surplusing work, designed to carry flood water not required to be stored in the reservoir, safely to the river lower down. 2M

**a) Free fall spillway** 2M

In this type of spillway, the water freely drops down from the crest, as for an arch dam (Figure 1) also for a decked over flow dam with a vertical or adverse inclined downstream face (Figure 2). Flows may be free discharging, as will be the case with a sharp-crested weir or they may be supported along a narrow section of the crest. Water freely falls from crest under the action of gravity. Since vacuum is created in the under-side portion of the falling jet, sufficient ventilation of nappe is required in order to avoid pulsating and fluctuating effects of the jet.

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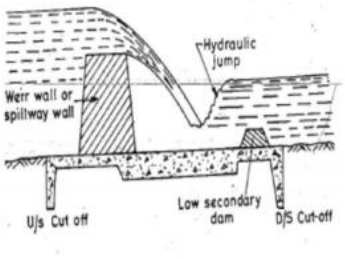


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**b) Ogee spillway**

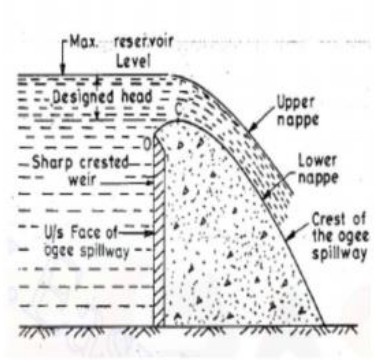


Fig Section of an Ogee spillway with vertical u/s face

The overflow type spillway has a crest shaped in the form of an ogee or S-shape. The upper curve of the ogee is made to conform closely to the profile of the lower nappy of a ventilated sheet of water falling from a sharp crested weir. Flow over the crest of an overflow spillway is made to adhere to the face of the profile by preventing access of air to the underside of the sheet of flowing water. 2M

Naturally, the shape of the overflow spillway is designed according to the shape of the lower nappe of a free flowing weir conveying the discharge flood any discharge higher than the design flood passing through the overflow spillway would try to shoot forward and get detached from the spillway surface, which reduces the efficiency of the spillway due to the presence of negative pressure between the sheet of 30 water and spillway

surface. For discharges at designed head, the spillway attains near-maximum efficiency.

2M

**c) Chute spillway**

A chute spillway, variously called as open channel or trough spillway, is one whose discharge is conveyed from the reservoir to the downstream river level through an open channel, placed either along a dam abutment or through a saddle. The control structure for the chute spillway need not necessarily be an overflow crest, and may be of the side-channel type, as has been shown in Figure.

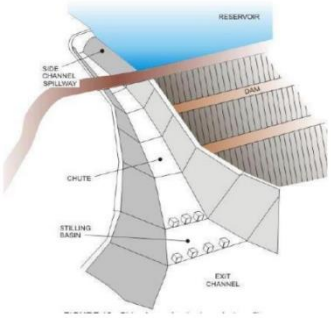


Fig- side channel entry to a Chute spillway

**d) Syphon spillway**

2M

A siphon spillway is a closed conduit system formed in the shape of an inverted U, positioned so that the inside of the bend of the upper passageway is at normal reservoir storage level. This type of siphon is also called a Saddle siphon spillway. The initial discharges of the spillway, as the reservoir level rises above normal, are similar to flow over a weir. Siphon action takes place after the air in the bend over the crest has been exhausted. Continuous flow is maintained by the suction effect due to the gravity pull of the water in the lower leg of the siphon.

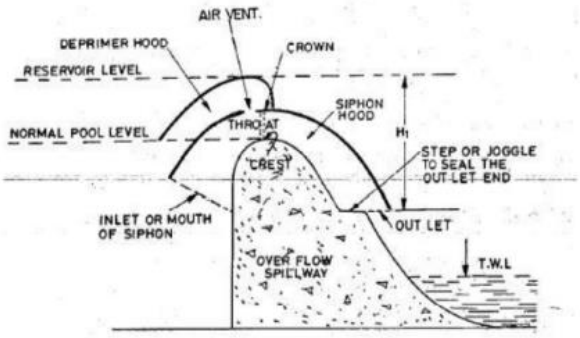


Fig- Siphon installed over the overflow spillway

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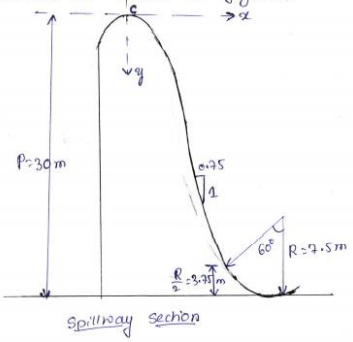
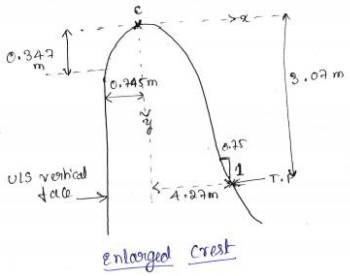
| 5 | **Design and draw the cross section of an Ogee spillway, when the maximum head over it is 2.67m, the height of spillway is restricted to 30m** | **10** | **CO3** | **PO3** | **L4** |

| | | |
|---|---|---|
| Ans | Solution:-<br>Data Given:<br>Max head over spillway = $H_d$ = 2.76 m.<br>height of spillway P = 30 m.<br>Since, $\frac{P}{H_d} = 10.87 > 1.33$, it is a high overflow spillway for which the effect of velocity of approach is negligible.<br>① Design of DIS profile:<br>Let us keep u/s face of the spillway as vertical.<br>The dis profile suggested by WES, is given by<br>$x^{1.85} = 2 H_d^{0.85} y$<br>Hence $y = \frac{x^{1.85}}{2 \times H_d^{0.85}} = \frac{x^{1.85}}{2 \times 2.76^{0.85}}$ ($\because H_d = 2.76m$)<br>$\boxed{y = \frac{x^{1.85}}{4.74}} \longrightarrow ①$<br>Assuming the tangent point for the dis slope as<br>0.75(H) : 1(V)<br>$\frac{dy}{dx} = \frac{1}{0.75} \longrightarrow ②$ | 2M |
| | ② Differentiating the eq$^n$ ① w.r.to x, we get<br>$\frac{dy}{dx} = \frac{1.85 x^{1.85-1}}{4.74} = 0.39 x^{0.85} \longleftarrow ③$<br>equating eq$^n$s ② & ③<br>$0.39 x^{0.85} = \frac{1}{0.75}$<br>$\therefore x = (3.42)^{1/0.85}$<br>$\boxed{x = 4.25 m}$<br>$\therefore$ from eq$^n$ ① $y = \frac{4.25^{1.85}}{4.74}$ ; $\boxed{y = 3.07 m}$<br>Hence co-ordinates of the tangent points are<br>$(x, y) = (4.25_m, 3.07_m)$<br>$\therefore$ The co-ordinates of DIS profile are $\left\{ y = \frac{x^{1.85}}{4.75} \right\}$<br>x(m) y(m)<br>0 0<br>0.5 0.058<br>1.0 0.210<br>1.5 0.446<br>2.0 0.759<br>2.5 1.147<br>3.0 1.607<br>3.5 2.137<br>4.0 2.736<br>4.25 3.07 | 2M |

| | | |
|---|---|---|
| | ② Determination of ogis profile:<br>The ogis profile is given by<br>$y = \frac{0.724(x+0.27H_d)^{1.85}}{H_d^{0.85}} + 0.126H_d - 0.4315H_d^{0.375}(x+0.27H_d)^{0.625}$<br>The curve extends up to $x = -0.27H_d$<br>Taking $H_d = 2.76m$<br>$y = \frac{0.724(x+0.27\times2.76)^{1.85}}{2.76^{0.85}} + 0.126\times2.76 - 0.4315\times2.76^{0.375}(x+0.27\times2.76)^{0.625}$<br>$y = 0.305(x+0.745)^{1.85} + 0.347 - 0.63(x+0.745)^{0.625}$<br>This curve will extend upto $x = -0.27\times2.76$<br>$x = -0.745m$<br>Hence the value of y co-ordinate are calculated for the value of x<br>x(m) y(cm)<br>-0.1 0.0035<br>-0.2 0.0158<br>-0.4 0.066<br>-0.6 0.170<br>-0.7 0.252<br>-0.745 0.347 | 2M |
| | ③ Determination of dis Bucket.<br>A reverse curve at the toe is provided to form a bucket. The radius of the bucket is generally kept at $R = \frac{P}{4} = \frac{30}{4} = 7.5m$<br>The bucket will subtend an angle of 60° at the centre, as shown in figure.<br>  <br><br>Spillway section<br>  <br><br>enlarged crest | 2M<br><br>2M |

*#132, AECS Layout, IT Park Road, Kundalahalli, Bangalore – 560 037 T:+9180 28524466 / 77*

**CMR**
**INSTITUTE**
**OF TECHNOLOGY**

## Department of Civil Engineering

CI:
**Prof. Usha A**

CCI:
**Prof. Divya Viswanath**