NEPAL ENGINEERING COUNCIL

LICENSE EXAMINATION PREPARATION COURSE
FOR
CIVIL ENGINEERS
on
Hydropower Engineering

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8.4 Head-works of run-of-River (ROR) plants :

8.4.1 Components of at typical ROR Plant

8.4.2 Design of Intake

8.4.3 Methods of Bed and Suspended Load Handling

8.4.4 Design of Settling Basin (Particle and Concentration Approach)

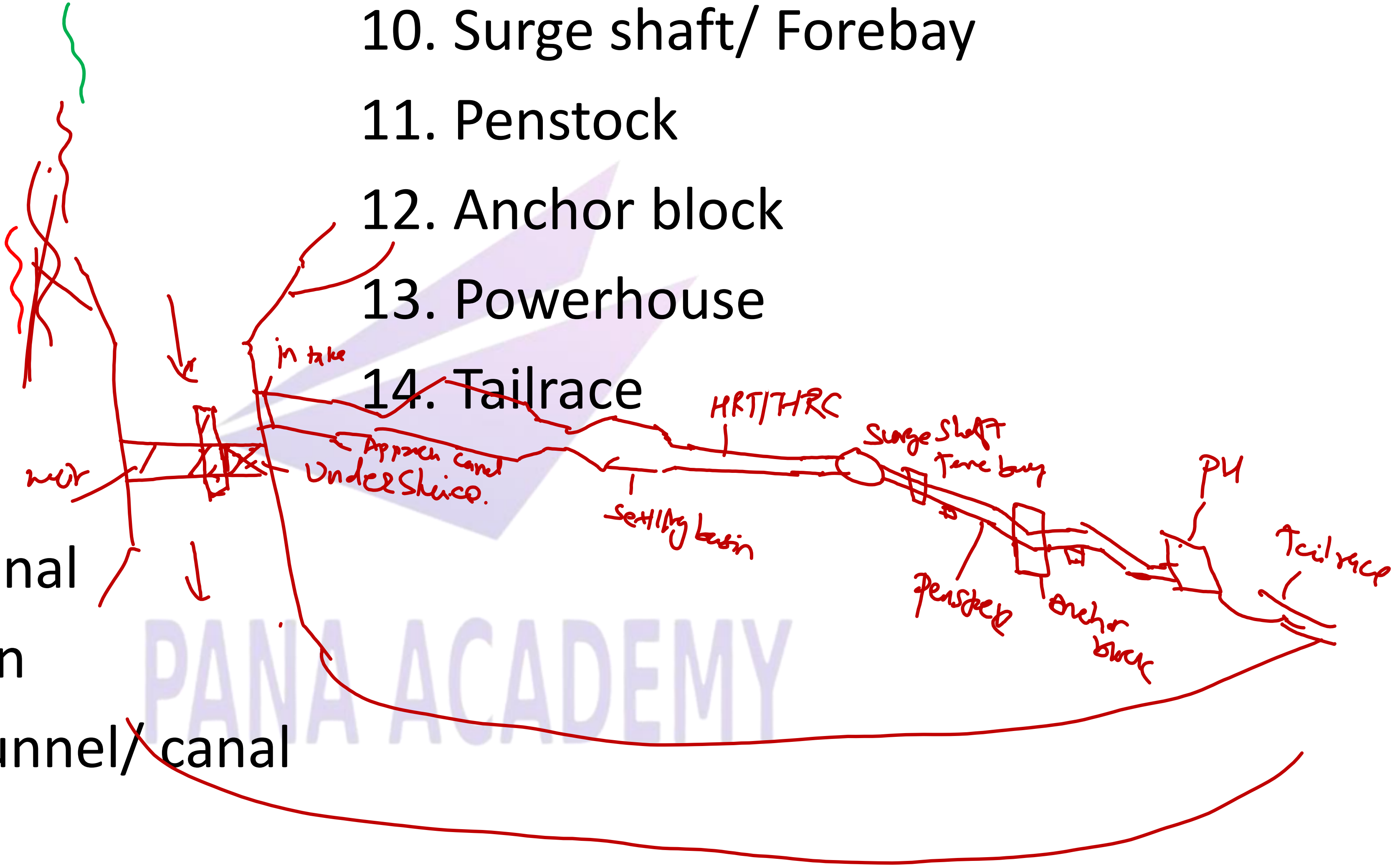
8.4.5 Estimation of Sediment Volume in Settling Basin

8.4.6 Flushing of Deposited Sediments

8.4.7 Estimation of Flushing Frequency for Sediments

8.4.1 Component of run-of-River (ROR) plants :

1. Weir
2. Undersluice
3. Divide Wall
4. Flood wall
5. Intake
6. Gravel trap
7. Approach canal
8. Settling basin
9. Head race tunnel/ canal
10. Surge shaft/ Forebay
11. Penstock
12. Anchor block
13. Powerhouse
14. Tailrace



8.4.1 Component of run-of-River (ROR) plants :

8.4.2 Design of Intake

Intake is the hydraulic structure provided at the mouth (entrance) of a water conveyance system to withdraw water from the reservoir or river to power house.

Location of intake:

It has to be decided based on following primary considerations:

- Adequate inflow
- Less silt inflow
- Least head loss
- Least Environmental impact

8.4.2 Design of Intake

Depending upon the type of power plant and its layout:

A) ROR type plant

draw water from fresh continuous river flow without any appreciable pondage

i. Side (lateral) intake

- Usually adopted when power house is away from dam, mild slope of river

ii. Frontal intake

- Suitable for relatively clean water.
- Suitable for storage or peaking type plants

iii. Drop intake

- Suitable for Minimum Bed load
- For steep rivers with rocks in river beds

8.4.2 Design of Intake

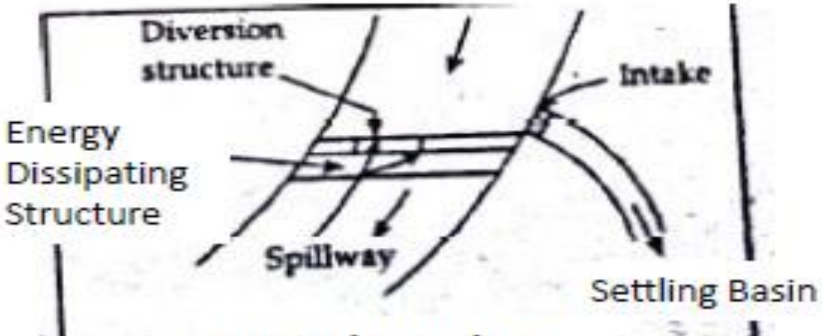


Fig: Side Intake

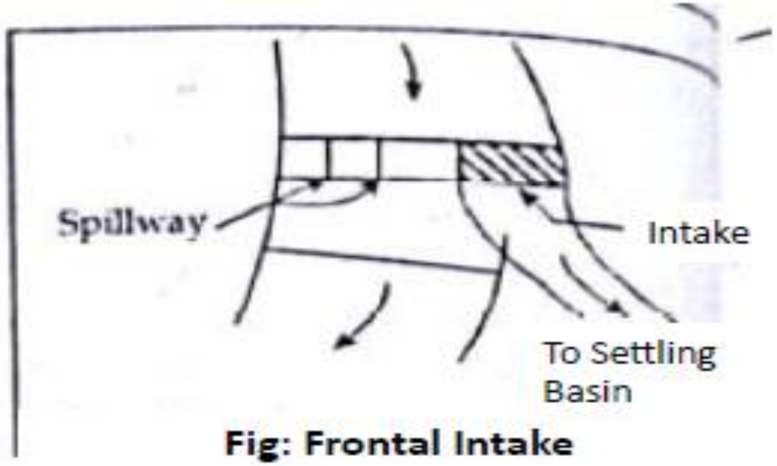


Fig: Frontal Intake

8.4.2 Design of Intake

Depending upon the type of power plant and its layout:

B) Reservoir Intake

i. Dam Intake:-provided on body of dam

ii. Conveyance intake:

iii. Re-entrant intake:- u/s face of the intake

iv. Shaft or Glory hole intake

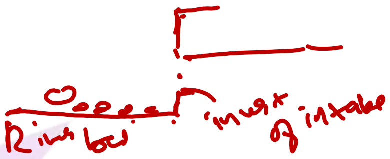
v. Tower intake: used on large project where wide fluctuation of water level

8.4.2 Design of Intake

Design of intake structure

(i) Selection of Type of intake:

Based on site and hydraulic conditions either side, frontal, trench, pressure, non-pressure intake is adopted.



ii) Determine the capacity of intake

The design discharge should be taken as 10-20% more than that of turbine discharge

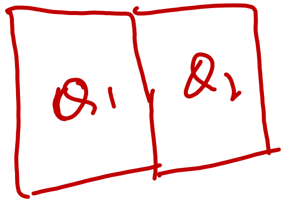
iii)Fixing intake invert level:

Based on sediment content (bed load) in the river and experience on design and construction, invert level shall be 0.5 m to 2 m above the under sluice level according to the site condition

8.4.2 Design of Intake

(iv) Satisfy velocity Criteria:

The entrance velocity should be less than 0.6m/s to 0.8m/s however upto 1m/s for small system.



(v) Determination of number of opening

(vi) Account the contraction loss due to the pier, abutment: generally effective length is taken as 0.9-0.95 times the actual opening.

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8.4.2 Design of Intake

(vii) Intake opening/orifice- is designed as broad crested weir with submergence or free flow condition depending upon the water level at u/s, d/s and on the weir. The intake opening under the gate control can also be designed based on orifice flow equation: $\boxed{Q_d = A*C*\sqrt{2g}*(H-h))}$

$Q = C_d\sqrt{2gH} * Area$

Where, H=river water level =depth of river water in front of intake

h=canal water level=depth of water in canal

C=constant depends on the shape of opening. For sharp edge and roughly finished opening=0.6 and for carefully finished=0.8

(viii) Calculate hydraulic loss:

- trash rack loss
- entrance loss
- transition loss
- gate loss

8.4.3 Method of Bed and Suspended Load Handling

Method which may adapt to control the deposition of sediment of RoR projects is

- Catchment management(treatment)
- Control of sediment deposition
- By designing and operating such that water having higher sediment content is discharged to d/s through undersluice
- Construction of sediment or silt excluder and ejector
- Silt excluder are constructed on bed of river, u/s of head regulator. While silt extractor are constructed on the bed of canal and little dis d/s from head regulator
- Construction of sedimentation tank, gravel trap, settling basin
- Frequent and timely flushing provision

8.4.4 Design of Settling Basin

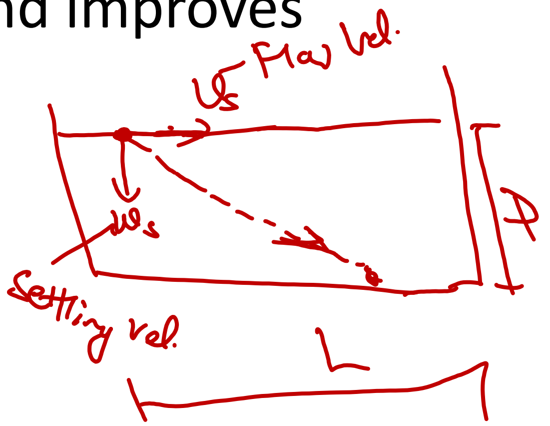
Settling basin is a structure designed to settle down the suspended sediment present in diverted water to avoid abrasion of sediment particles with penstock pipe and turbine runner plate.

It is constructed on the headrace Canal and located just downstream of the gravel trap immediate after the intake structures. It is built to remove **suspended sediment particles** that cannot be removed by gravel trap and reduces turbulence level in water flow to allow sediment particles to settle

8.4.4 Design of Settling Basin

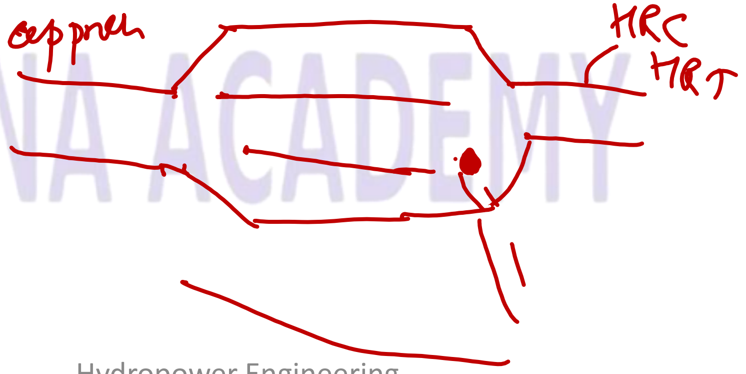
Design Criteria and Principle of Settling Basin

- Greater the basin surface area and lower the through velocity, the smaller the particles that can settle.
- Targeted to remove 95 to 100% of the sediment load
- Removal of sediment load reduces the damage on turbines and improves hydraulic efficiency



Design of the settling basin aims to meet the following criteria:

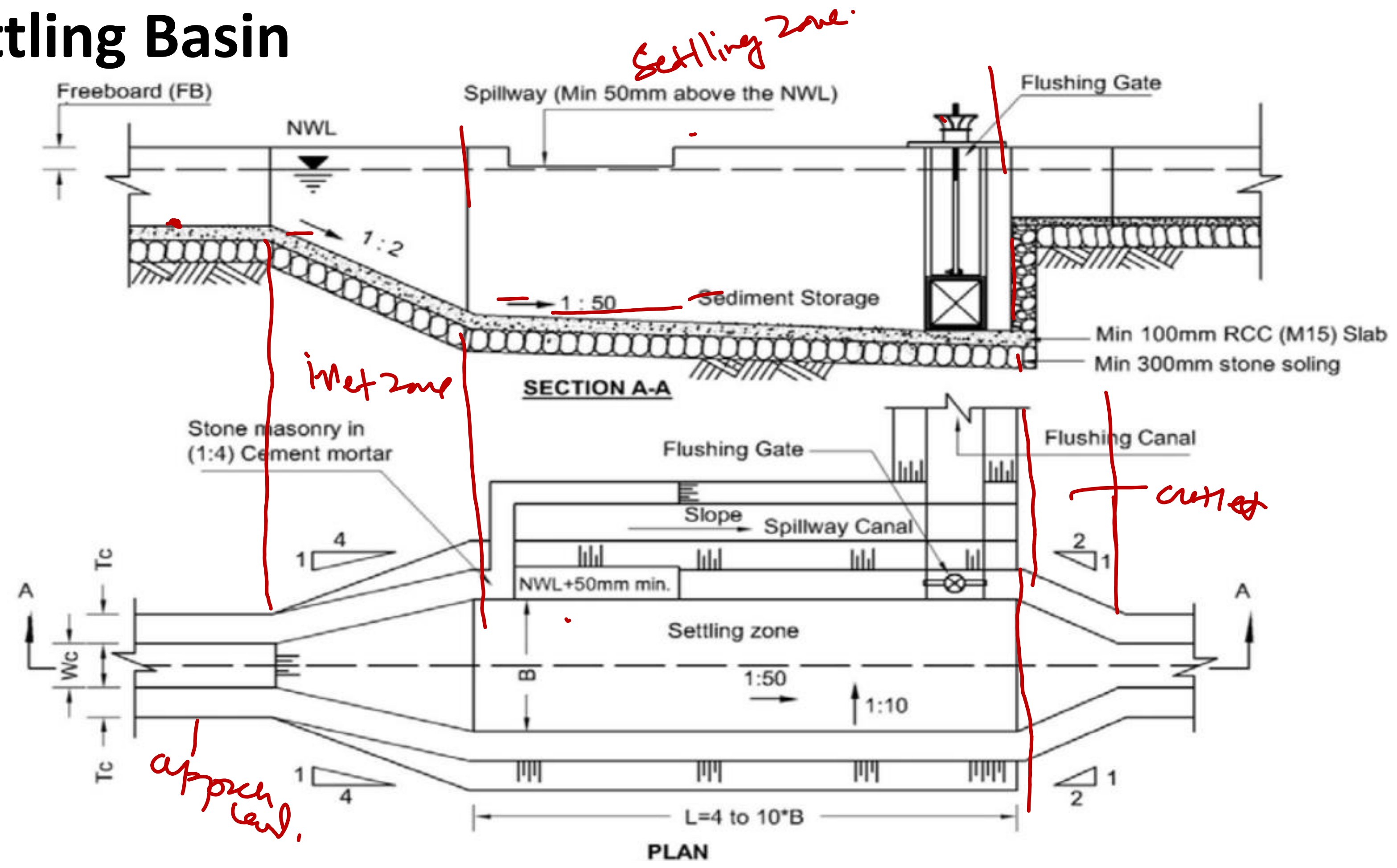
1. Optimum Removal of Sediments
2. Efficient Flushing
3. Settling Capacity
4. Storage Capacity



8.4.4 Design of Settling Basin

Components of Settling Basin

a. Inlet zone
b. Settling zone &
c. Outlet Zones



8.4.4 Design of Settling Basin

1. Inlet Zone:

It's a transition designed for slowing down the velocity of flow by gradually increasing the depth of basin along with gradual expansion in width.

1:4

Expansion in width : 7 to 10 degrees upto 1:5 gives smooth transition

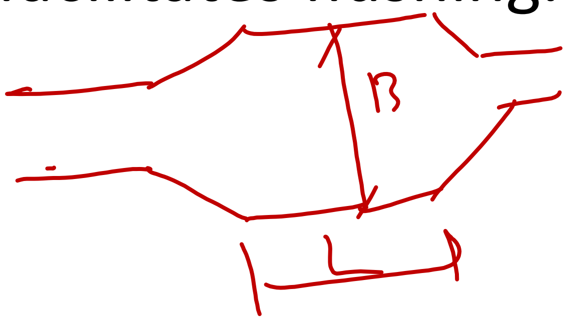
Vertical expansion ratio 1:2 (around 27 degrees)

8.4.4 Design of Settling Basin

2. Settling Zone:

It is the main part of the basin. The settling of suspended particles takes place here. The provision of flushing should be placed at the end and floor slope of 1:20 to 1:50 in settling zone facilitates flushing.

- L/B ratio = 4 to 10 (recommended)
- Depth to width ratio: 1 to 1.5 (recommended)
- Adopt depth of basin= 3 to 5 m



8.4.4 Design of Settling Basin

3. Outlet Zone

It is the part of basin designed to get back the flow into the conveyance system with design velocity by gradually narrowing the width and depth of basin. The transition is more abrupt.

- Horizontally 1:2
- Vertically 1:1

8.4.4 Design of Settling Basin

Design of Settling Basin

There are two main approaches to designing a settling basin with respect to resulting trap efficiencies of basin

a. Particle Approach

b. Concentration Approach

8.4.4 Design of Settling Basin

A. Particle approach

V_s

w

In this approach, following design steps should be followed:

1. Calculate surface area, A = KQ/ω where, K = 1.2-1.5
2. Calculate L and B using the relation L/B = 4 -10 (Normally 6 adopted) and A=L*B
3. Calculate flow velocity using relation: V = a√d where d = diameter of particle in mm. According to T.R camp, the value of constant a is,

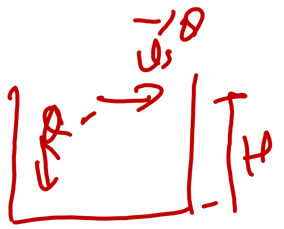
$$V = a\sqrt{d_{mm}}$$

$0.45\sqrt{d_m}$

$$a = 0.36 \text{ for } d > 1\text{mm}$$
$$= 0.44 \text{ for } 0.1 < d < 1\text{mm}$$
$$= 0.51 \text{ for } d < 0.1\text{mm}$$

[designed to remove sediment with diameter less than 0.25mm; Mosonyi suggest velocity range of 0.4 -0.6 m/s but kept upto 0.35 m/s due to length restriction]

8.4.4 Design of Settling Basin



4. Calculate depth of basin using equation: H = Q / (V*B)

5. Check for L and B:

The equation to check length of stilling basin is given by M.A. Velikanov **which is as,**

$$L = \frac{\lambda^2 * (\sqrt{H} - 0.2)^2 * V^2}{7.51 * \omega^2}, \text{ where } \lambda = 1.5 \text{ (usually)}.$$

Similarly, $B = 4.75 * \sqrt{Q}$

6. Considering Turbulence: $L = \dfrac{D*V}{\omega - \dfrac{0.132*V}{\sqrt{H}}}$

8.4.4 Design of Settling Basin

$h \downarrow$ $U \rightarrow$

B. Concentration or trap Efficiency approach:

Vetter's Equation:

The trap efficiency of basin (η) = =1- $e^{\wedge -(\omega A/Q)}$.

$1 - e^{-(\omega A/Q)}$, $A = B*L$

This concentration approach is applied if sediment concentrations < 2000 ppm.

8.4.5 Estimation of Sediment Volume in Settling Basin

The following are the sediment problems in RoR plants,

i. Very less or no pondage in ROR plants

ii. Decreases the conveyance capacity

iii. Damages underwater hydro-mechanical equipment

⇓ Turbine, penstock

iv. thereby reduces plant efficiency

v. leads to frequent maintenance and revenue losses

8.4.5 Estimation of Sediment Volume in Settling Basin

Now, the following points steps should be consider while estimating sediments in the basin,

1. Calculate the sediment load using formula,

$$\boxed{S_{load} = Q * T * C}$$

Where Q= discharge in cumec (m^3/s)

T= sediment emptying frequency in second

C= sediment concentration in kg/cumec (generally 2 kg/cumec)

8.4.5 Estimation of Sediment Volume in Settling Basin

2. Volume of sediment,

$$V_{sediment} = (S_{load}/S_{density} * \text{packing factor})$$

$S_{load} = Q\,T\,C$ — m^3/s, sec, kg/m^3.

The storage space is achieved by increasing the depth of the basin as

$$Y_{storage} = V_{sediment}/A \text{ — } L*B.$$

$V_{sl} = \frac{S_{load}}{densi} * p.f$

Where $Y_{storage=}$ storage depth in the settling basin below hydraulic depth,

A = plan area= L*B

8.4.5 Estimation of Sediment Volume in Settling Basin

Unless mentioned, the following should be taken while designing,

- Retention time (T) = 8 hrs (See)
- Packing Factor (P) = 0.3 – 0.5
- Density (ρ) = 2600 kg/m^3

8.4.6 Flushing of Deposited Sediment

Continuous Flushing Desander-

This desander with continuous flushing system can be designed to supply continuous sediment free water to conveyance system by simultaneous setting of sediment and flushing of deposited sediments from bottom of basin.

- 10-20% of extra water should essential for flushing.

Key points:

- more suitable with regard to power plant operation as flushing operation do not interfere the power generation

8.4.6 Flushing of Deposited Sediment

Discontinuous Flushing Desander:

This desander with periodic flushing can be designed to operate in two distinct phases.

-In the first phase, sediment is allowed to settle down the basin and sediment free water as possible shall be conveyed to conveyance system.

-In second stage, the deposited sediments are flushed out either stopping the supply of water to conveyance system or supply by another basin

8.4 Multiple Choice Questions

1. Settling basin is located in the canal at

a) Upstream of Gravel trap

b) Downstream of gravel trap

c) Anywhere

d) None of the above

2. The settling basin are designed to settle

a) Coarse material

b) Suspended material

c) Both (a) and (b)

d) None of the above

8.4 Multiple Choice Questions

3. Which of the following design criteria are important for design of settling basin

a) Optimal removal of sediment

b) Efficient flushing

c) Settling capacity

d) All of the above

4. In which zone of settling basin, the transitions from canal to settling zone occurs

a) Settling Zone

b) Inlet Zone

c) Outlet zone

d) Transition zone

8.4 Multiple Choice Questions

5. In which zone of settling basin, the transitions from settling zone to headrace occurs
a) Settling Zone
b) Inlet Zone
c) Outlet zone
d) Transition zone

6. In which range the gradual expansion of inlet gives smooth transition in settling basin
a) 7° to 10°
b) 10° to 15°
c) 10° to 12°
d) 5° to 7

8.4 Multiple Choice Questions

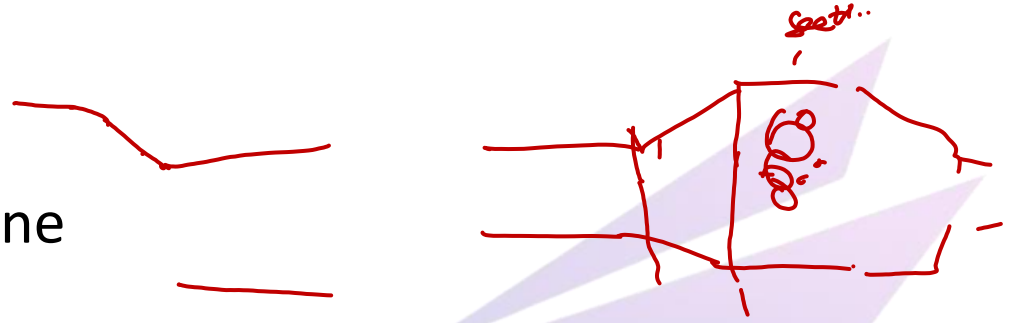
7. In which zone of settling basin the suspended particles starts to settle down

a) Settling Zone

b) Inlet Zone

c) Outlet zone

d)Transition zone



8. Which zone is larger in length in settling basin?

a) Settling Zone

b) Inlet Zone

c) Outlet zone

d) Transition zone

8.4 Multiple Choice Questions

9. If Q is the discharge in m^3/sec, T is is sediment emptying frequency in seconds and C is sediment concentration kg/m^3 then sediment load can be computed from the above

a) S=QxTxC

c) S=T/(QxC)

b) S=Q/(TXC)

d) S=C/(QXT)

10. The methods which are adopted in sediment handling are

a) Removing sediment inflow through watershed management and erosion control

b) Removal of deposit from reservoir

c) Construction of settling basin

d) All of the above

8.4 Multiple Choice Questions

11. In case of valley type of plant, which type of intake is suited

(a) side intake

(b) frontal intake

(c) Canal intake

d) dam intake

12. Which of the following is NOT a factor that affects the design of an intake structure?

a. Velocity of the water

b. Size of the sediment

c. Type of turbine used

d. Volume of water to be diverted

8.4 Multiple Choice Questions

13. River intake is usually situated on

(a) Convex side of curve

(b) concave side of curve

(c) D/S of severe outfall

(d) none of above

14. In a reservoir with widely fluctuations in water level and/or to draw quality water, the intake is usually

(a)Tower type

(b) submerged type

(c) Drop intake type

(d) frontal intake type

8.4 Multiple Choice Questions

15. Bottom intake is suitable for project having

(a) steep gradient of river

(b) flat gradient of river

(c) high sediment laden river

(d) all of the above

16. Undersluice is constructed

(a) to flush away accumulated bed load in front of the intake towards the d/s of the river.

(b) to flush away heavy debris

(c) to flush dead animal and fishes

(d) None of the above

8.4 Multiple Choice Questions

17. Which device is used for silt removal after it enters the canal?

(a) Silt Excluder

(b) Silt Ejector/ silt extractors (Canal)

(c) Weir

(d) Barrage

18. What device is placed in front of head regulator for silt removal?

a) Weir

b) Silt Extractor

c) Silt Excluder (River म)

d) Barrage

8.4 Multiple Choice Questions

19. Design discharge of intake will be taken as
(a) as 10 to 20% of turbine discharge to account for flushing
(b) has 100 to 120% of turbine discharge to account for flushing
(c) has 50 to 60% of turbine discharge to account for flushing
(d) all of the above

20. The packing factor of sediment submerged in water is generally taken as,
(a) 0.25
(b) 0.5
(c) 0.8
(d) 1.2

8.4 Multiple Choice Questions

21. A settling basin is designed to remove solids greater than 0.008mm from a maximum inflow of 0.25m³/sec. Particles of the minimum size settle at velocity (Vs) of 5.9*10-5 m/sec. The necessary area for a 1m deep basin is

a) 4237 m^2

b) 2492 m^2

c) 9242 m^2

d) 3724 m^2

$Q = 0.25 \, m^3/s$

$(\downarrow) V_s = 5.9 \times 10^{-5} \, m/s$

Area (A) = ?

$Q = A \times V$

A =

22. What is the volume of silt accumulated in a period of 10 days if the sediment conc. of the flow is 5kg/m3 for a discharge of 25cumecs and silt density of 2400kg/m3 and a packing factor of 1/2

a. 45000 m3

b. 37500m3

c. 21000m3

d. 250000m3

C

Q

T

sec,

0.5

S_s | Sdensity

$S_{load} = Q \times T \times C$

$Vol = \frac{S_{load}}{S_{density}} \times P.F = 2250 \, m^3$

Thank You