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NEPAL ENGINEERING COUNCIL

LICENSE EXAMINATION PREPARATION COURSE FOR CIVIL ENGINEERS

on

Hydropower Engineering

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8.5 Water Conveyance Structure

8.5.1 Hydraulic Tunnels, x section and hydraulic design (velocity and sizing)

8.5.2 Tunnel Lining

8.5.3 Design of forebay and Surge tanks

8.5.4 Design of penstock and pressure shaft

8.5.5 Hydraulic Transients (water hammer)

8.5.1 Hydraulic Tunnels, x section and hydraulic design

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Hydraulic tunnel is an underground water conduit formed by excavation without removing the overlaying rock.

8.5.1 Hydraulic Tunnels, x section and hydraulic

8.5.1 Hydraulic Tunnels, x section and hydraulic

Advantages :

- Shortest route
- Optimum space Utilization/consumption
- Less environmental effect
- Less Seismic Effect

Disadvantages:

- High construction cost
- long construction period
- High construction risk
- Additional lightening and ventilation cost

8.5.1 Hydraulic Tunnels, x section and hydraulic

<u>Types</u>

Based on Alignment:

- Horizontal Tunnels having small slope 1:1000 in bottom,
- Shaft tunnel for vertical alignment,
- Incline shaft for steep slope greater than 1:100.

8.5.1 Hydraulic Tunnels, x section and hydraulic

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Based on Purpose or function:

a) water carrying tunnel(Hydraulic Tunnel): are wet and impermeability and porosity important

b) service tunnels: are dry used for services like

access/passage tunnel, cable tunnel, ventilation tunnel (fans fitted at the end)

Water carrying tunnels(Hydraulic Tunnel) may be

i. head race tunnel to gain head
ii. power tunnel to supply water to the powerhouse
iii. Tail race tunnel to convey water from the power house to the river
iv. Diversion tunnel for diverting the water from the construction site

8.5.1 Hydraulic Tunnels, x section and hydraulic

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Based on Pressure of flowing fluid:

a) Pressure Tunnel:

- The tunnel in which the flow takes place with pressure is called pressure tunnel.
  - For e.g: Headrace tunnel.

b) Non pressure Tunnel:

- The tunnel in which the flow takes place as free surface exposed to atmosphere. The flow in the tunnel is open channel flow.
  - For e.g: Spillway Tunnel, Diversion tunnel, Tailrace Tunnel, etc. .

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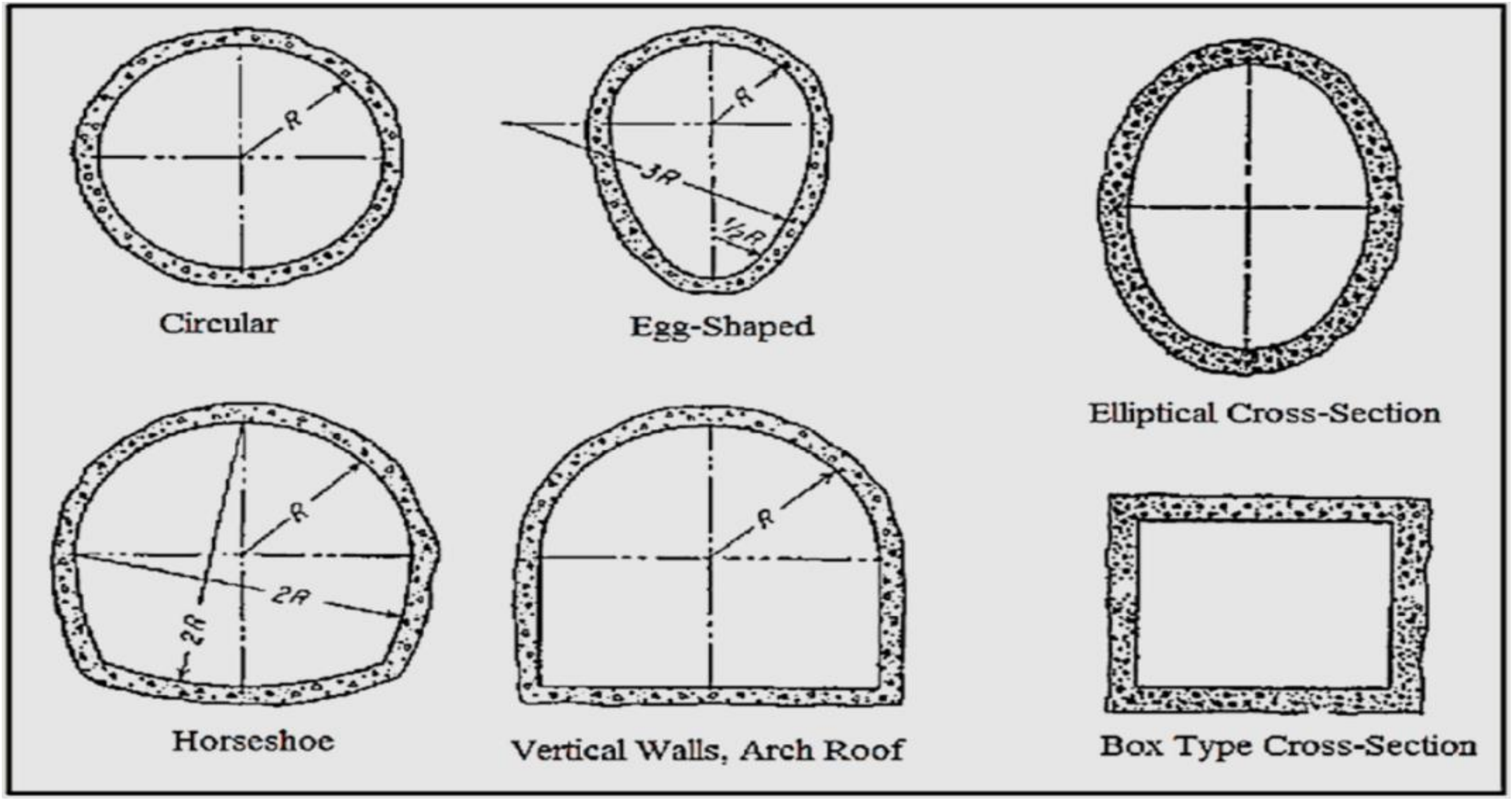
Based on shape:



8.5.1 Hydraulic Tunnels, x section and hydraulic

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1. Circular Section

- most suitable from structural considerations.

- difficult for excavation, particularly where the cross sectional area is small.

- Suitable for tunnel subjected to high pressure but not having good quality rock

8.5.1 Hydraulic Tunnels, x section and hydraulic

2. D-Shaped Section

- Suitable for tunnels located in good quality rocks.
- Gives more working compared to other sections
- Suitable for tunnels not subjected to internal pressures

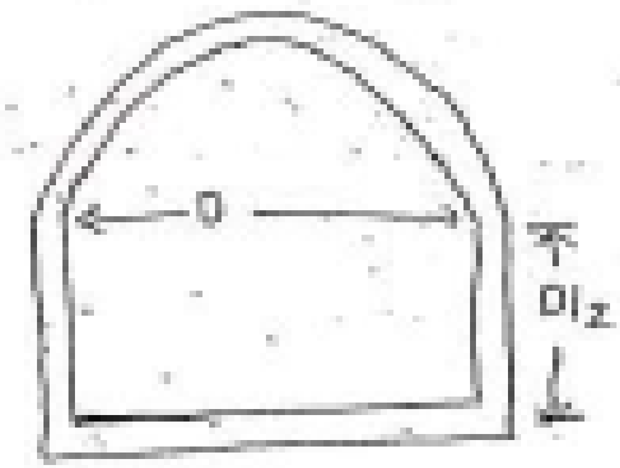

Fig: D-shaped section

8.5.1 Hydraulic Tunnels, x section and hydraulic

3. Horse-shoe or Modified Horse-shoe Sections

- Have the advantages of both circular and D-shaped tunnels
- structurally strong to withstand external rock and water pressure.
- suitable, where moderately good rock is available, advantages of a flatter invert are required for construction purposes and the tunnel has to resist internal pressure.

Fig: Horse-Shoe section

8.5.1 Hydraulic Tunnels, x section and hydraulic

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4. Egg Shaped Sections

Egg section is preferred,

- when rock is stratified, soft and very closely laminated (sand, stone, slates, ect) and
- where rock falls are caused due to high external pressure and tensile stresses in rock are prone

8.5.1 Hydraulic Tunnels, x section and hydraulic

Tunnel Alignment:

Some points to be noted during tunnel alignment selection:

- Shortest as far as possible (economic, minimum head loss)
- Straight as far as possible (bends increase construction cost as well as head loss)
- Easily accessible near the entrance and exit for easy construction
- Careful selection of the alignment with no weathered, loose or fractured layers of rock

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Tunnelling Sequence:

1. Drilling
2. Loading, Charging & Blasting
3. Ventilation or Defumming
4. Mucking and Haulage of rock pieces
5. Scaling
6. Ribbing(Fixing steel Support work) OR Rock bolting
7. Concreting the space between rock and steel support

8.5.1 Hydraulic Tunnels, x section and hydraulic

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Method of Tunneling:

1. Drift Method
2. Heading And Benching Method
3. Full Face Method
4. NATM Method [New Austrian Tunneling Method]
5. Cut and cover Method
6. Tunnel boring Method (TBM)

8.5.1 Hydraulic Tunnels, x section and hydraulic

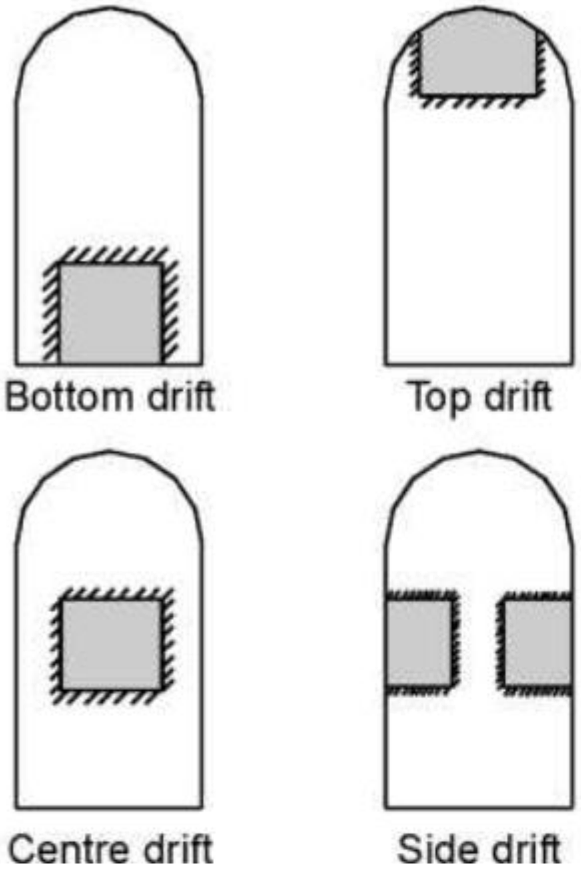
1. Drift Method

- A drift is a small tunnel driven through all or a portion of the length of the tunnel prior to the excavating full bore.
- The drift method of tunneling is a commonly used technique in the construction of tunnels, especially in rock formations

Type:

a) Central drift
b) Side Drift
c) Top Drift
d) Bottom drift

8.5.1 Hydraulic Tunnels, x section and hydraulic



Type of drift	Purpose
Central Drift method	Time-consuming, good ventilation, eliminates supporting platform
Side Drift method	Used for tunneling work of a large cross-section
Bottom Drift method	Are of low height roof can be properly lined and platform avoided
Top Drift method	For smaller section and most popular section type of drift.

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2. Heading And Benching Method

- Suitable for **Soft Rock Tunneling** of medium And large size tunnel
- If rock is hard and self supporting, then top heading advances ahead by one round over the bottom
- Top heading will need support and bench will provide platform for this
- Heading is usually 3-3.5 m ahead of bench


Temporary invert

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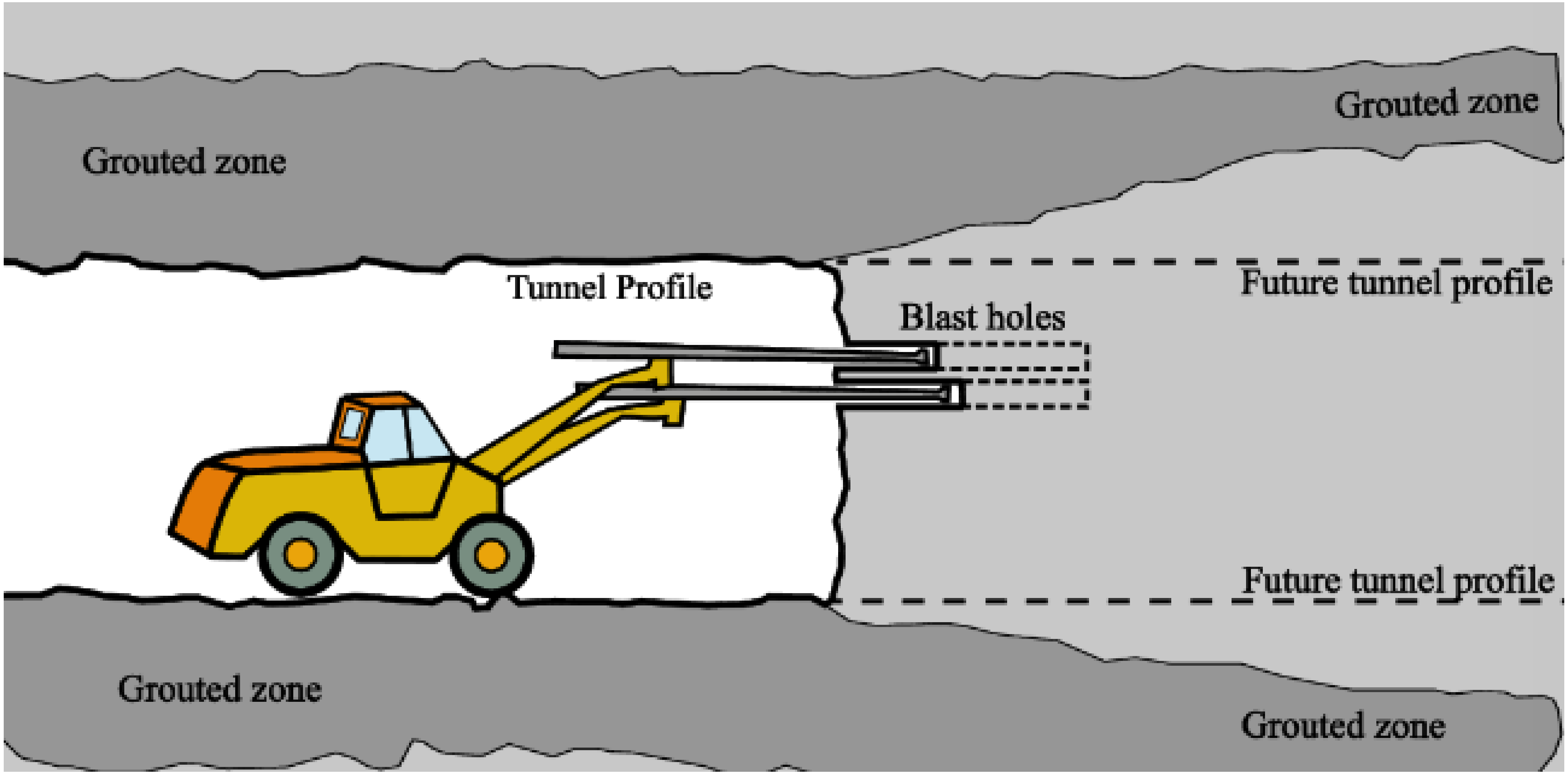
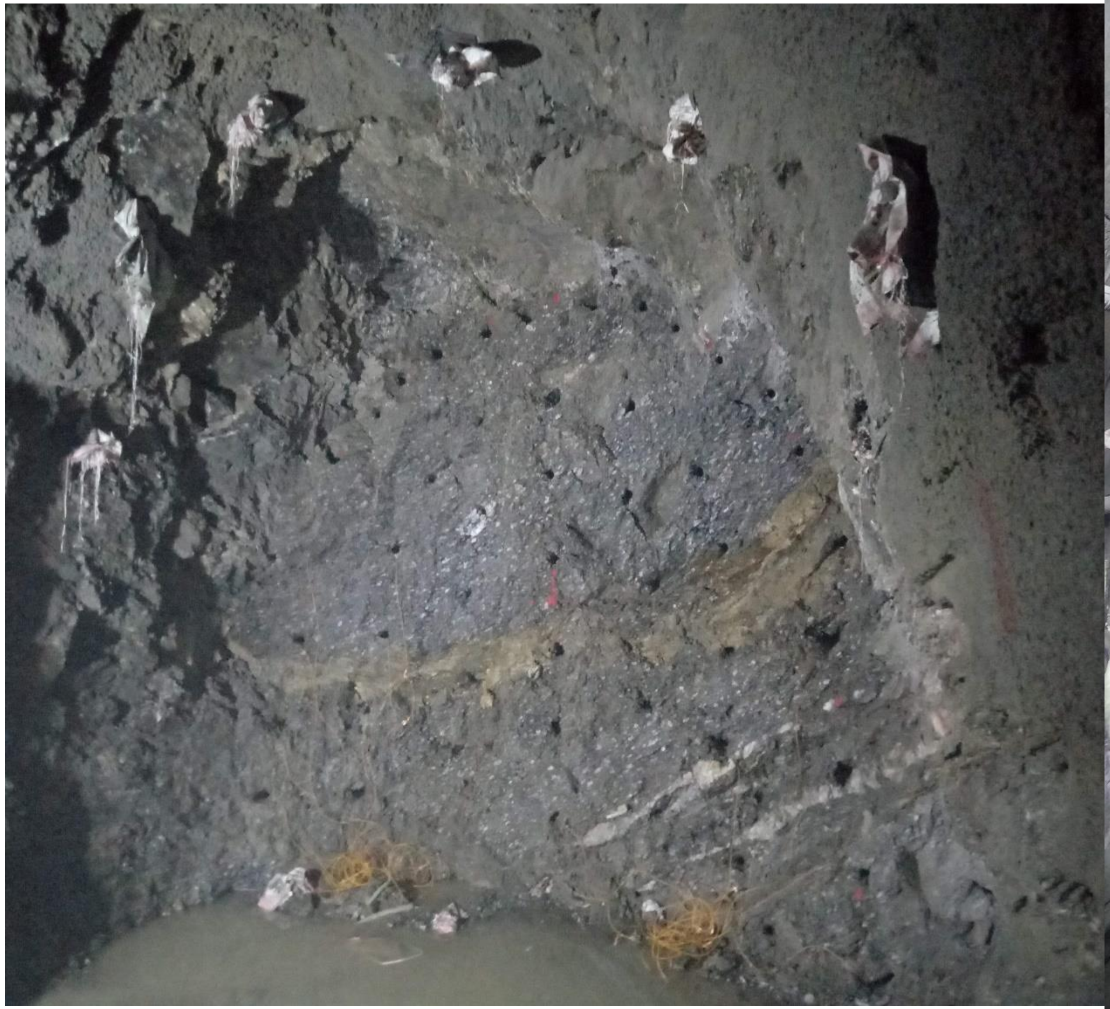
3. Full Face Method

- In this whole section of tunnel is attacked at the same time. It is suitable for small c/s area about 3m diameter.
- Entire section is drilled, the holes are charged and explosive are discharged
- This method of tunnel is continuous
- Popular due to result of equipment development such as Shield and Tunnel boring method.


Grouted zone
Grouted zone
Tunnel Profile
Future tunnel profile
Blast holes
Future tunnel profile
Grouted zone
Grouted zone



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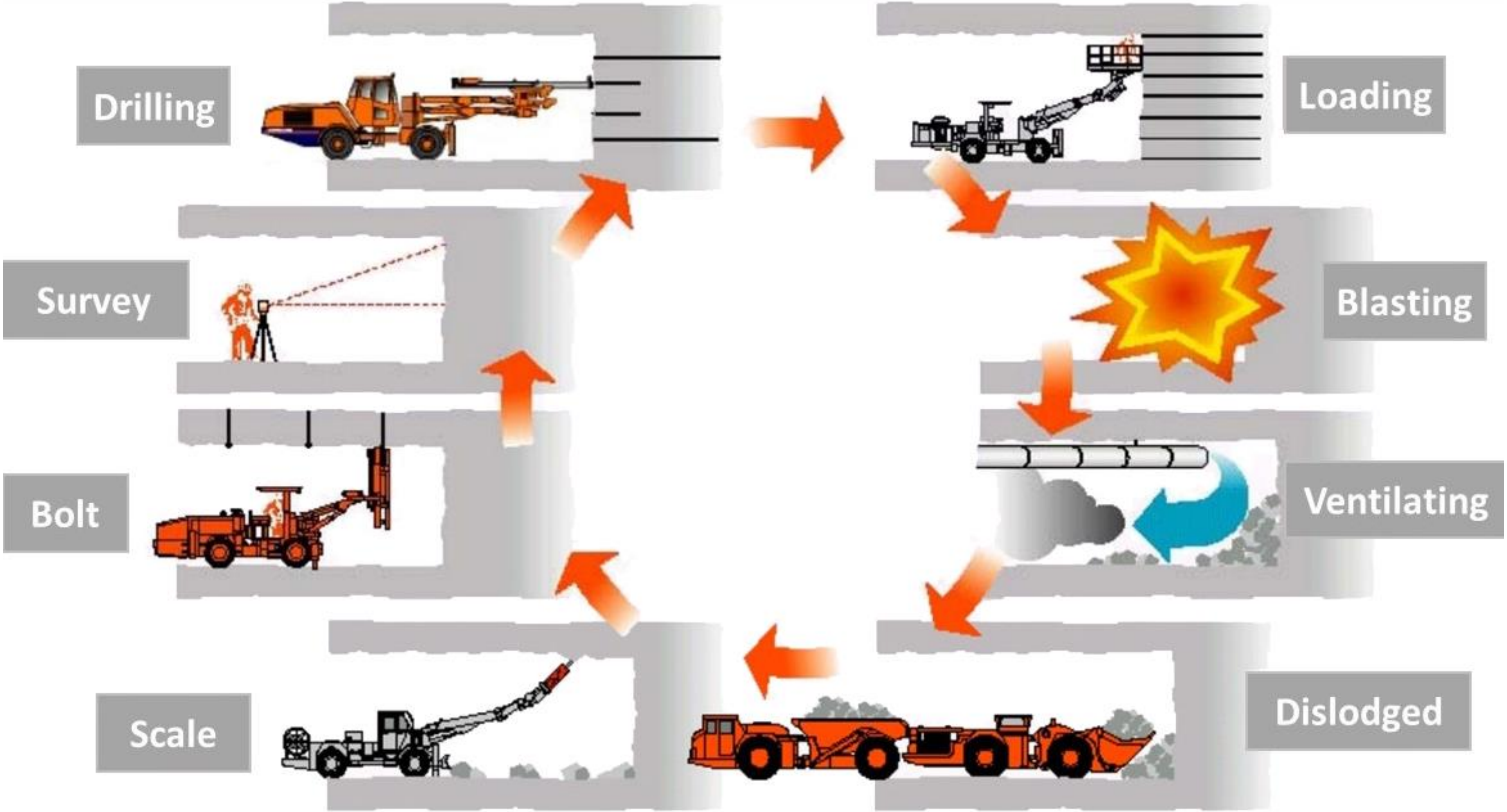
4. NATM method

- The New Austrian Tunneling Method (NATM) is a tunnel construction technique characterized by its sequential excavation approach and flexible support systems.
- It involves excavating small tunnel sections while immediately providing temporary support, like shotcrete and rock bolts, to adapt to the ever-changing geological conditions.
- NATM relies on continuous monitoring, geological assessments, and adaptive design changes during construction to ensure safety and stability.


Drilling
Loading
Blasting
Ventilating
Dislodged
Scale
Bolt
Survey

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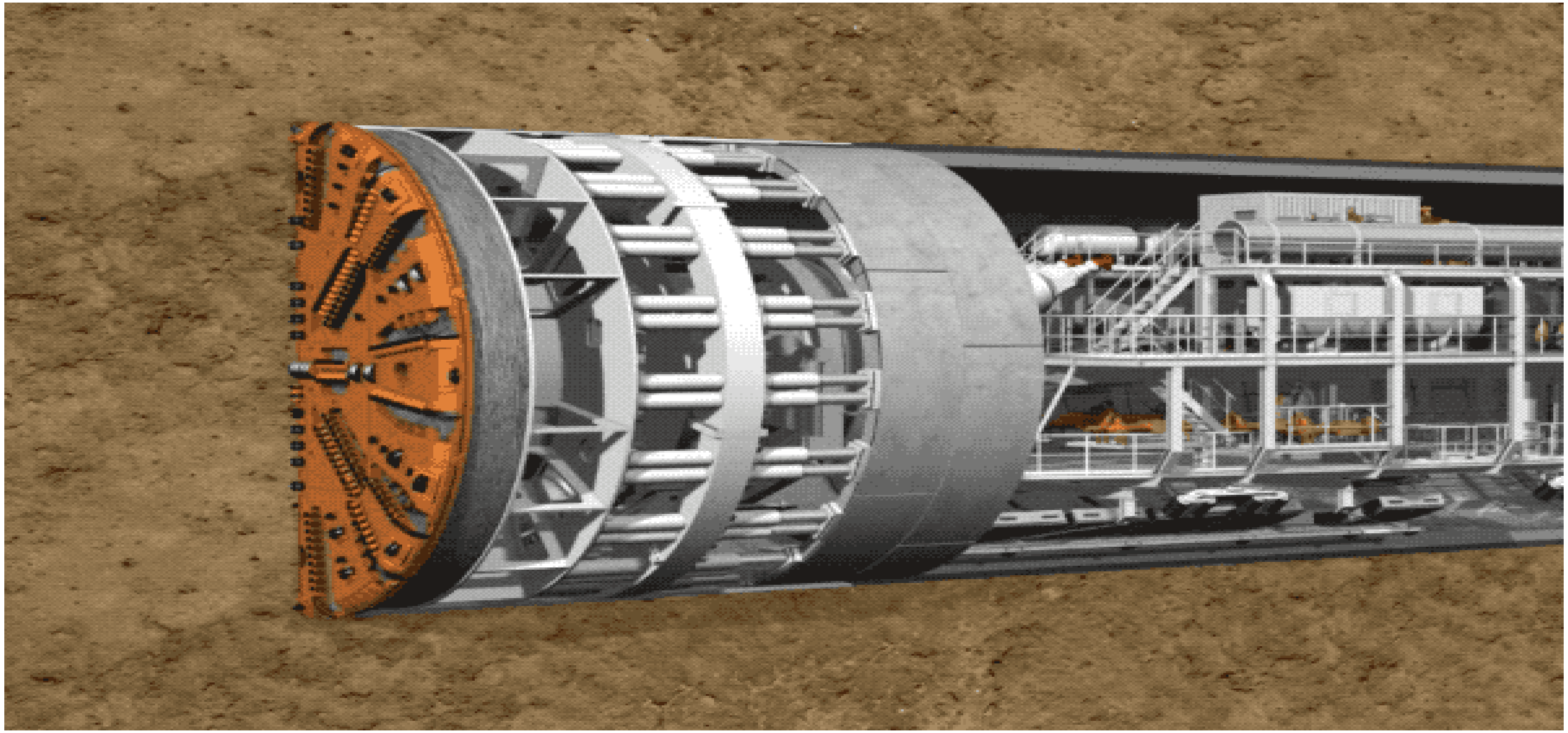
Tunnel Boring Machine (TBM):



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Tunnel Boring Machine (TBM):

- A tunnel boring machine is a machine that can excavate tunnels in a single operation, called full-face drilling.

- It has a rotating head with cutting parts and runs on hydraulic or electric motors, though its power supply is 100% electric

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Tunneling in Hard Ground:

Hard ground typically refers to rock formations that are capable of supporting themselves without significant external support. When tunneling through self-supporting rock, several methods can be used:

1. **Drill and Blast Method**: This traditional method involves drilling holes into the rock, filling them with explosives, and then detonating the explosives to break the rock into fragments that can be easily removed. This process is repeated until the tunnel is formed.
2. **Mechanical Excavation:** In some cases, mechanical equipment like tunnel boring machines (TBMs) can be used to bore through hard rock. TBMs are especially effective in homogeneous rock formations and can significantly speed up tunnel construction.
3. **Sequential Excavation**: Also known as the New Austrian Tunneling Method (NATM), this method involves excavating a small section of the tunnel, supporting it with temporary supports like rock bolts and shotcrete, and then moving forward. This process is repeated sequentially until the entire tunnel is completed.

8.5.1 Hydraulic Tunnels, x section and hydraulic

Tunneling in soft ground:

- Soft-ground tunneling methods are commonly used for urban services (subways, sewers, and other utilities).

- The tunnel structure in soft ground is generally designed to support the entire load of the ground above it, partly

- Soft-ground tunnels are typically circular in shape to inherit greater strength and readjust to future load changes.


8.5.1 Hydraulic Tunnels, x section and hydraulic

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Hydraulic Design of the Tunnel

1. Geometric Design of Tunnels:
   Tunnel geometry depends upon prevailing geological conditions, hydraulic requirements, structural requirements, and the judgment of the designer.
2. Widely used Tunnel Geometry:
   i. Circular Section
   ii. D-Shaped
   iii. Horse Shoe
   iv. Modified Horse Shoe

8.5.1 Hydraulic Tunnels, x section and hydraulic

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3. Size of Tunnel:

- Size is fixed based on functional requirements like discharge requirements, transportation requirement.

- Minimum diameter of the tunnel is fixed with consideration of transport, excavation, and hauling distance and should be greater than 2.0m in case of circular and greater than 1.9m in width and 2.1 meters in height in case of other tunnels.

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4. Flow Tunnel

a) Free Flow tunnel

Manning's formula: $Q = 1/n * A * R^{2/3} * S^{1/2} = 1/n * A * R^{2/3} * (hf/L)^{1/2}$

where,

A=tunnel cross-section area,

R=Hydraulic radius,

S=Slope,

L=Length of tunnel,

h_f =head loss in tunnel,

n=roughness coefficient ranging from 0.012-0.018 for tunnel.

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b) Pressure Flow Tunnel

Hydraulic design of the pressure flow is computed as the pipe flow and the head loss is computed using Darcy/Weisbach frictional factor.

Discharge through a pressurized hydraulic tunnel is calculated using a continuity equation with control volume approach: $Q = V * A$

And Frictional loss, $h_f = fLV^2 /2gD$

The friction coefficient *f* depends upon the Reynolds number and the relative roughness ks/D where ks is the equivalent sand grain roughness and its value depends upon the surface characteristics.

8.5.1 Hydraulic Tunnels, x section and hydraulic

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5. Velocity

For unlined tunnel 2 to 2.5 m/s,

Concrete lined tunnel 4 to 5 m/s,

Steel lined tunnel upto 9 m/s.

6. Slope of tunnel

- Headrace tunnel have gentle slope (1:1000 to 1:2000) up to surge tank.
- Steep slope in shaft tunnel.

7. Over Burden Pressure:

- At limiting condition the **Over burden rock pressure = Internal water pressure**

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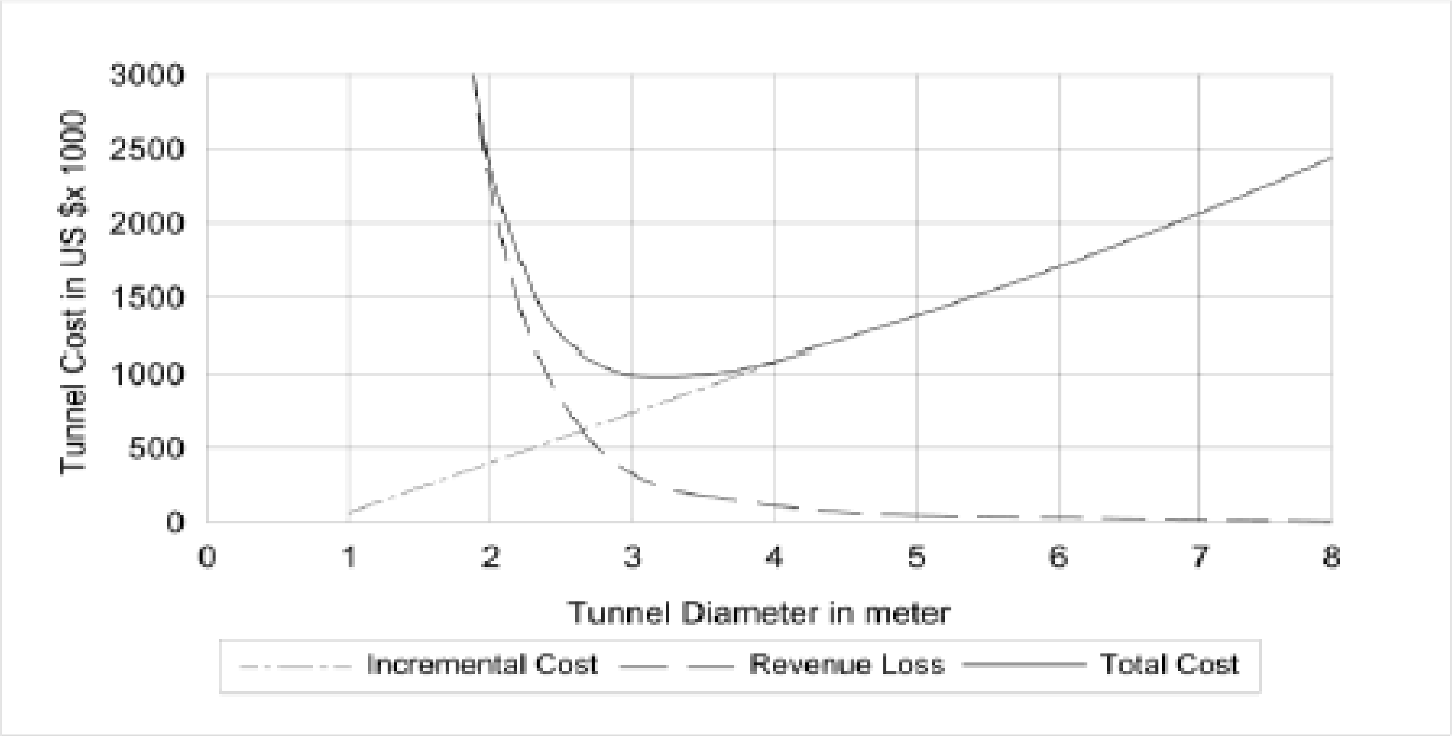
Hydraulic Design of Tunnel

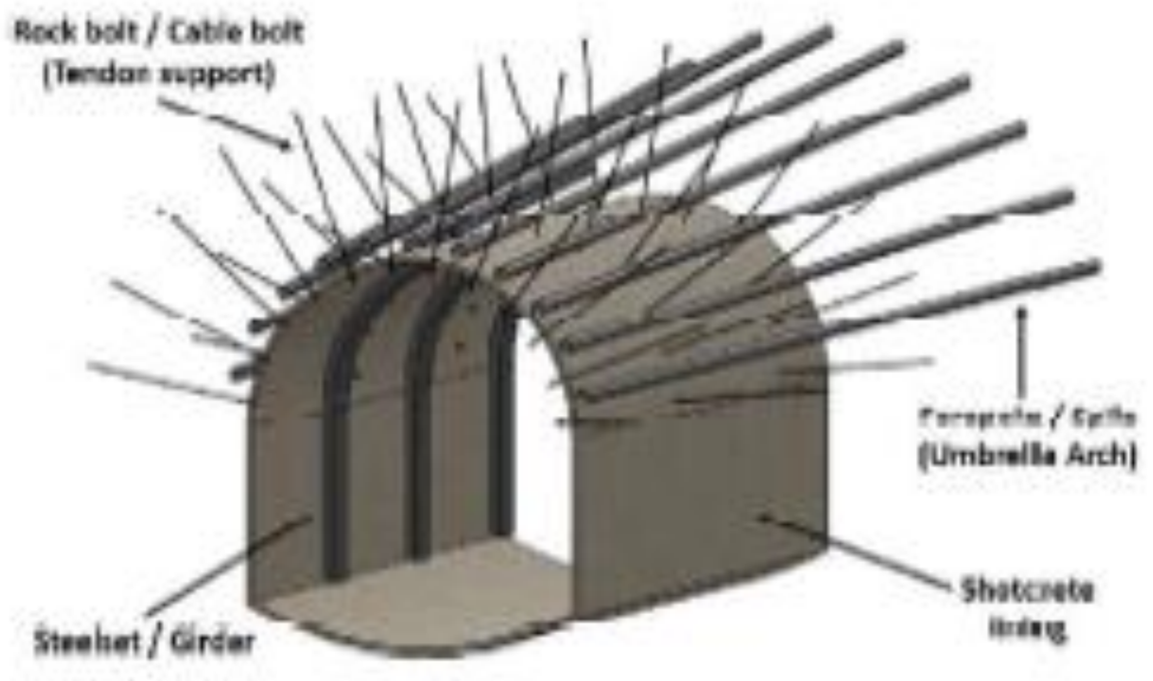


- Diameter is optimized based on Economic Consideration
  - Higher the diameter, construction cost increase but reduce head loss thus energy production increases getting more benefit against the increase cost of investment
  - Principle of optimization is same as that of the determination of optimum economic diameter of penstock pipe

8.5.1 Hydraulic Tunnels, x section and hydraulic

Concept of Tunnel Stability and Support or Protection Measures

- For the tunnel to be stable, it is necessary rock supports for the actual rock conditions in tunneling and excavation engineering works.
- Steel ribs
- Timber support
- Steel linear plate
- Rock bolts
- Wire mesh or perforated steel mats
- Shotcrete / Grouting
- Forepolling



8.5.2 Tunnel Lining

8.5.2 Tunnel Lining

- structures(grouting, RCC or steel lining) provided inside the tunnel for improvement of the strength of rocks in tunnel walls and imperviousness (impermeability) of the tunnel are called tunnel lining.
- After excavation of tunnel, lining is done to increase the hydraulic capacity, to reduce resistance, to increase strength, and to reduce losses from tunnel.

[Note: Empirical formula to calculate the thickness of tunnel lining in mm is 82D, where D is diameter of tunnel in m]

Lining is done when:

- High internal Pressure
- in strata of low strength
- to increase discharge carrying capacity.

8.5.2 Tunnel Lining

Main purpose of Tunnel Lining:

- Provide strength and stability in weaker strata or part
- to give correct section of tunnel
- to withstand soil internal pressures
- to reduce loss in friction
- keeps tunnel free from water percolation
- supports large slabs of rocks which might have been loosed during blasting

8.5.2 Tunnel Lining

8.5.2 Tunnel Lining

Types of Tunnel Lining:

- Plain Concrete Lining
- RCC Lining
- Steel Lining

Thickness of lining:

- Plain concrete lining: to resist outside external rock compressive pressure and low internal water pressure($h_w \leq 10m$). Thickness is in range 20cm – 60 cm
- RCC lining: for medium internal water pressure h_w>10m to 100m. Grouting is applied before RCC lining to improve strength of lining. Thickness is in range 20cm – 60cm.
- Steel Lining: for high internal water pressure like in pressure shaft tunnel with h_w> 100m. Thumb rule for minimum thickness of steel lining

  $t_{min}(cm) = \frac{D+50}{400}$, D is internal diameter of tunnel in cm

  Thickness of steel lining provided is generally 2 mm more than t_{min}.

8.5.3 Design of Forebay and Surge Tank

8.5.3 Design of Forebay and Surge tank

Forebay:

- Forebay is a quick storage transition structures constructed at the beginning of the penstock pipe which accommodates rejected flow during sudden shut down, supply flow during start up and reduce water hammer effect.
- Allows the transition from open channel to pressure flow.
- enlarged body of water provided just in front of the penstocks.
- if the powerhouse is located close to the dam, the reservoir itself acts as a fore bay/surge tank

8.5.3 Design of Forebay and Surge tank

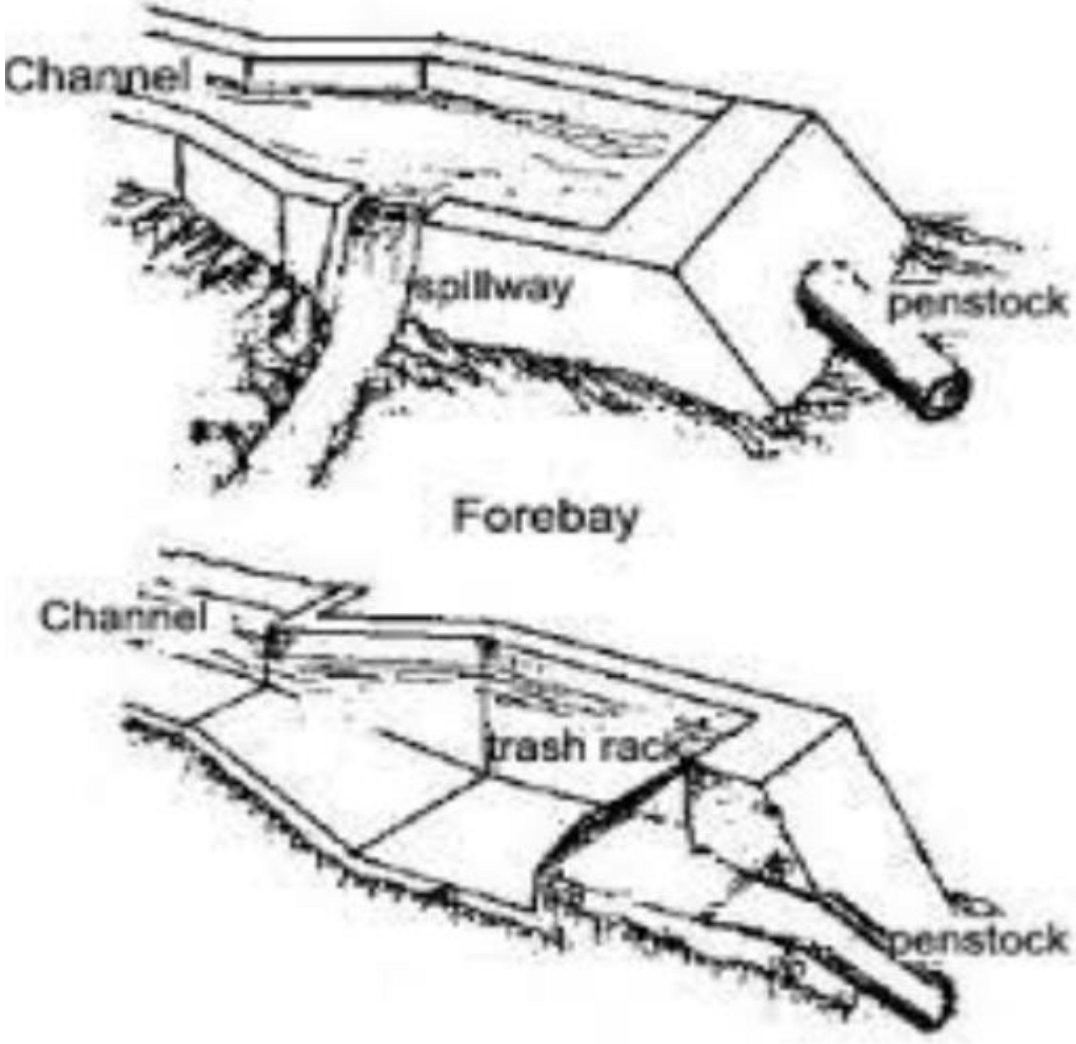
Function of forebay:

- To fulfill the immediate requirement of supplying water during turbine start up.
- To accommodate rejected water during closure and spill extra water
- It releases surge pressure as the wave travels out of the penstock pipe
- Also serve as secondary settiling basin and trap some particles that enter the headrace d/s of the settling basin.

Condition of applications:

Generally, forebay are applicable

- if power canal or pipe is used instead of tunnels.
- Sufficient space available for forebay construction


Channel
spillway
penstock
Forebay
Channel
trash rack
penstock

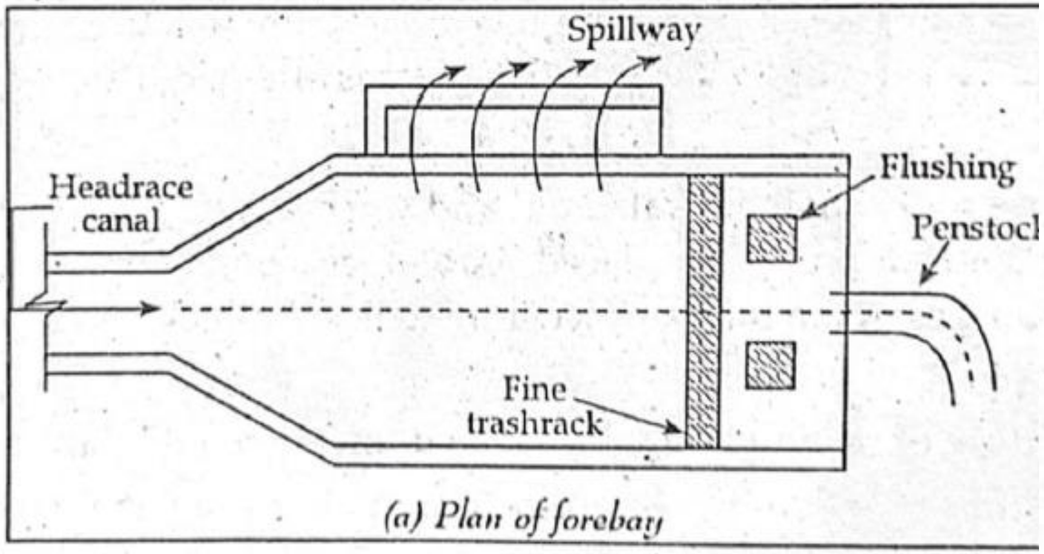
8.5.3 Design of Forebay and Surge tank

Parts/Component of Forebay

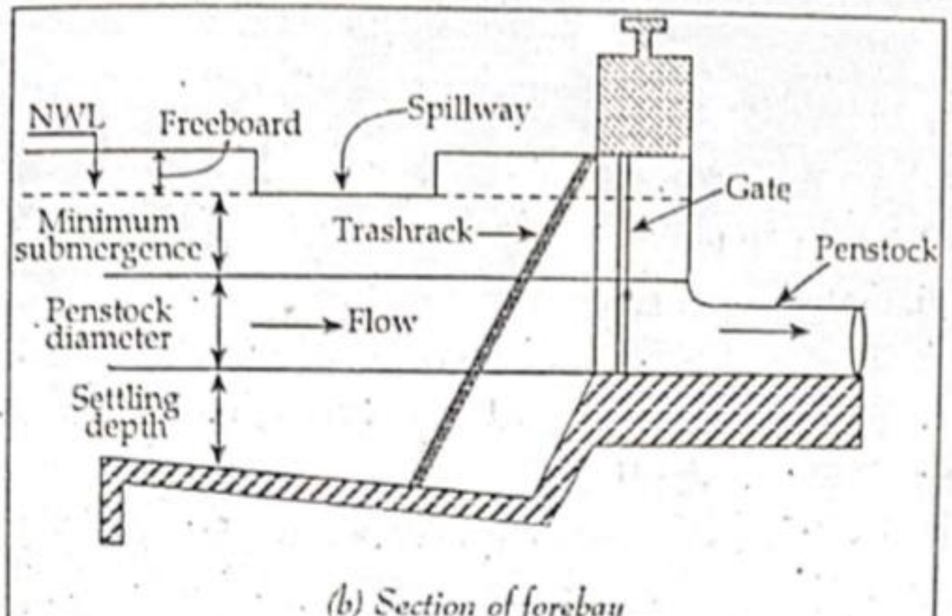
Following are the parts of the typical forebay:

i) Entrance bay or basin

ii) Spillway



(a) Plan of forebay



(b) Section of forebay

Figure: Forebay

iii) Flushing sluice

iv) Screens

v) Valve or gate chamber

vi) Conduit or penstocks inlet

8.5.3 Design of Forebay and Surge tank

Design of Forebay structures

- Volume of forbay, V= Q*detention time(t) , generally, t=2-3 minutes
- L/B of the forebay is in the range of 3 to 10 based on site condition
- Minimum submergence (hs) = 1.5 Vp^2 / 2g

  or hs = 0.5*Vp* $\sqrt{D}$

  take, whichever is greater.

where, V_p = velocity of flow in penstock pipe ,

D= Diameter of penstock pipe

8.5.3 Design of Fore bay and Surge tank

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- The Horizontal velocity of flow (v) is limited in the range of 0.2 m/s to 0.8m/s
- Depth of Forebay(H) = Depth of submergence(hs) + Penstock diameter(Dp) + Settling depth($h_{settling}$) + Freeboard(FB)
- Where,

  FB= 0.3-1m ,

  $h_{settling}$= settling depth of the fore bay=0.3 m(300mm) minimum

  B = Q/(H* v) , v is velocity

  L= V/HB , V is volume

8.5.3 Design of Forebay and Surge tank

Check for length of fore bay:

$L_{spillway} = Q/CH^{3/2}$,if $L > L_{spillway}$,ok.

Where, H = overtopping head = 0.7m maximum,

C = coefficient depending upon spillway type

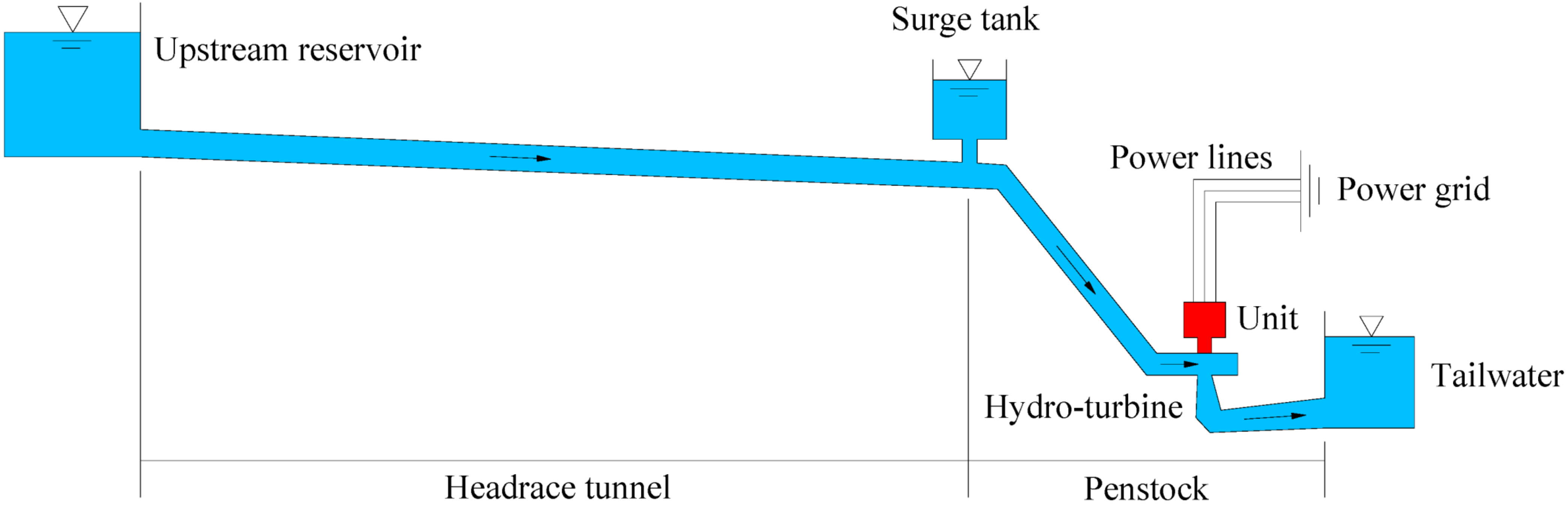
=1.7 for sharp crested,

=2.2 for ogee spillway

8.5.3 Design of Forebay and Surge tank

Surge tank:

- Surge Tank is a quick storage or transition structure constructed between headrace pressure tunnel and steep slopping penstock pipe l.



8.5.3 Design of Forebay and Surge tank

5.5.1. Functions of surge tank

- Provide a supply of water when the valve is suddenly opened
- To reduce the water hammer pressure
- It store water at the line of load rejection until the penstock velocity has been decelerated to the new steady state valve.

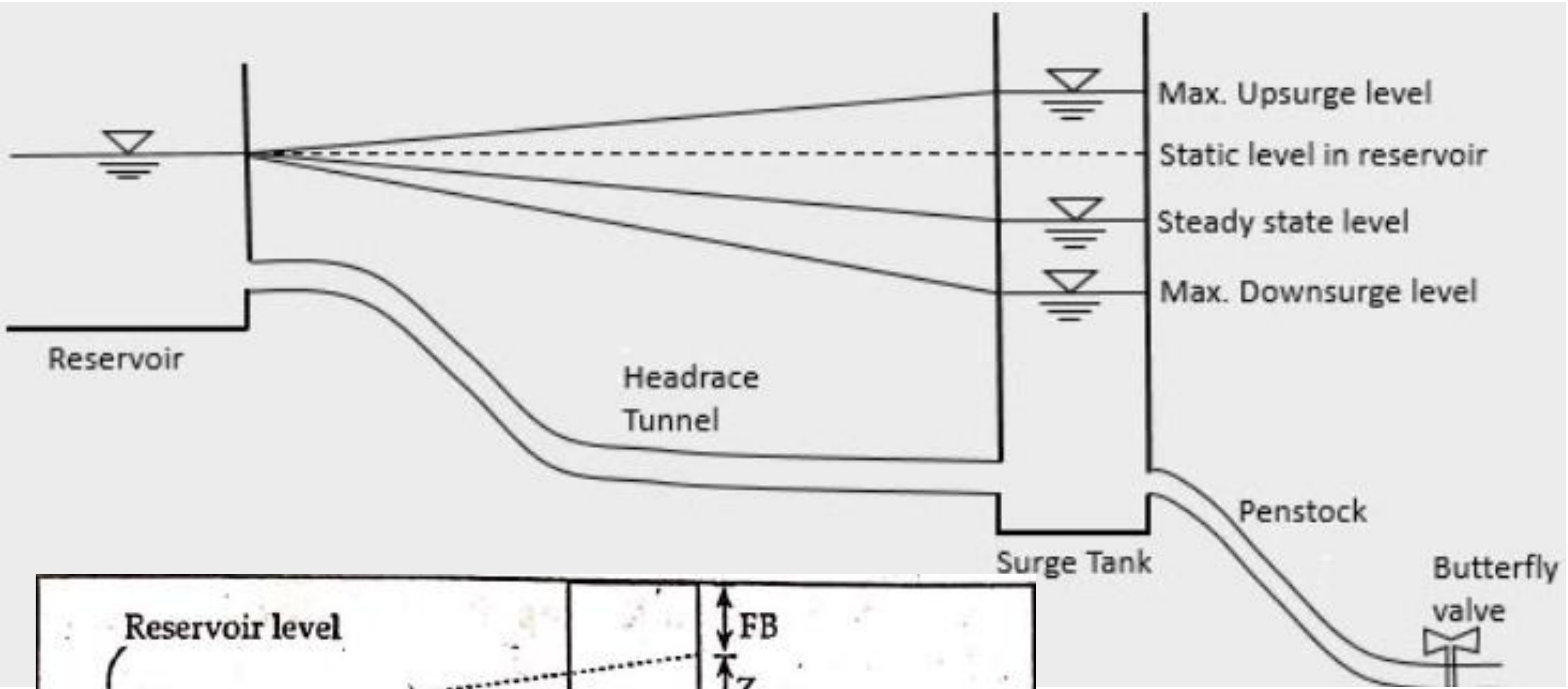
8.5.3 Design of Forebay and Surge tank

- **Design considerations of Surge tank:**

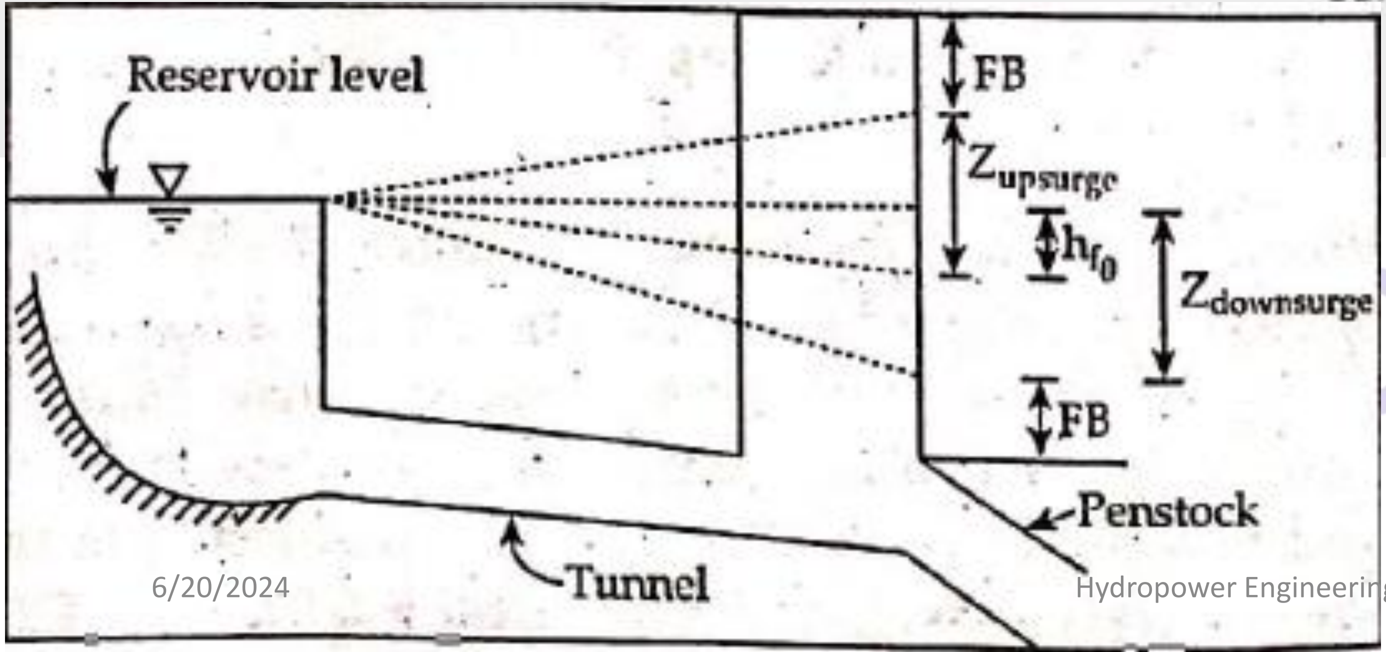
i. **Stability condition:** Small water level fluctuation during the operation should be damped and water in the surge tank should be made stable.

ii. **Up-surging conditions:** The top elevation of surge tank should be higher than the up-surging water level due to rapid interception of full load.

iii. **Down-surge condition:** The bottom elevation of surge tank should be lower than the down surging level. In no case air should be drawn into the pipe.



Max. Upsurge level
Static level in reservoir
Steady state level
Max. Downsurge level
Reservoir
Headrace
Tunnel
Penstock
Surge Tank
Butterfly
valve



Reservoir level
FB
$Z_{upsurge}$
h_{f_0}
$Z_{downsurge}$
FB
Penstock
Tunnel

8.5.3 Design of Forebay and Surge tank

Design of Surge Tank:

- $A_{st,\ min} = A_t\ L_t\ V_t^{\ 2} / 2gh_f\ (H_g - h_f)$
- $A_{st} > A_{st,\ min}$
  - where, H_g = Gross head
  - h_f = head loss in headrace tunnel
  - A_{st} = Cross-sectional area of headrace tunnel
- In actual practice, factor of safety (Fs) = 1.5 is taken, & the cross-section area =Fs* As, min
- Time of oscillation (T) = $2*\pi*\sqrt{(L_t\ A_{st} / gA_t)}$
- Ht. of surge tank= Zup + Zdown - h_f + FB

8.5.3 Design of Forebay and Surge tank

Design of Surge Tank:

$$Z_{max.upsurge} = Z_{max.} * \left(1 - \frac{2*P}{3} + \frac{P^2}{9}\right)$$

$$Z_{max.downsurge} = Z_{max} * (-1 + 2*P) \,,$$

Also, $P = h_f / Z_{max}$,

$$Z_{max} = V_t * \sqrt{\frac{Lt*At}{g*Ast}}$$

Where,

L_t= length of tunnel,

V_t = velocity of water in tunnel,

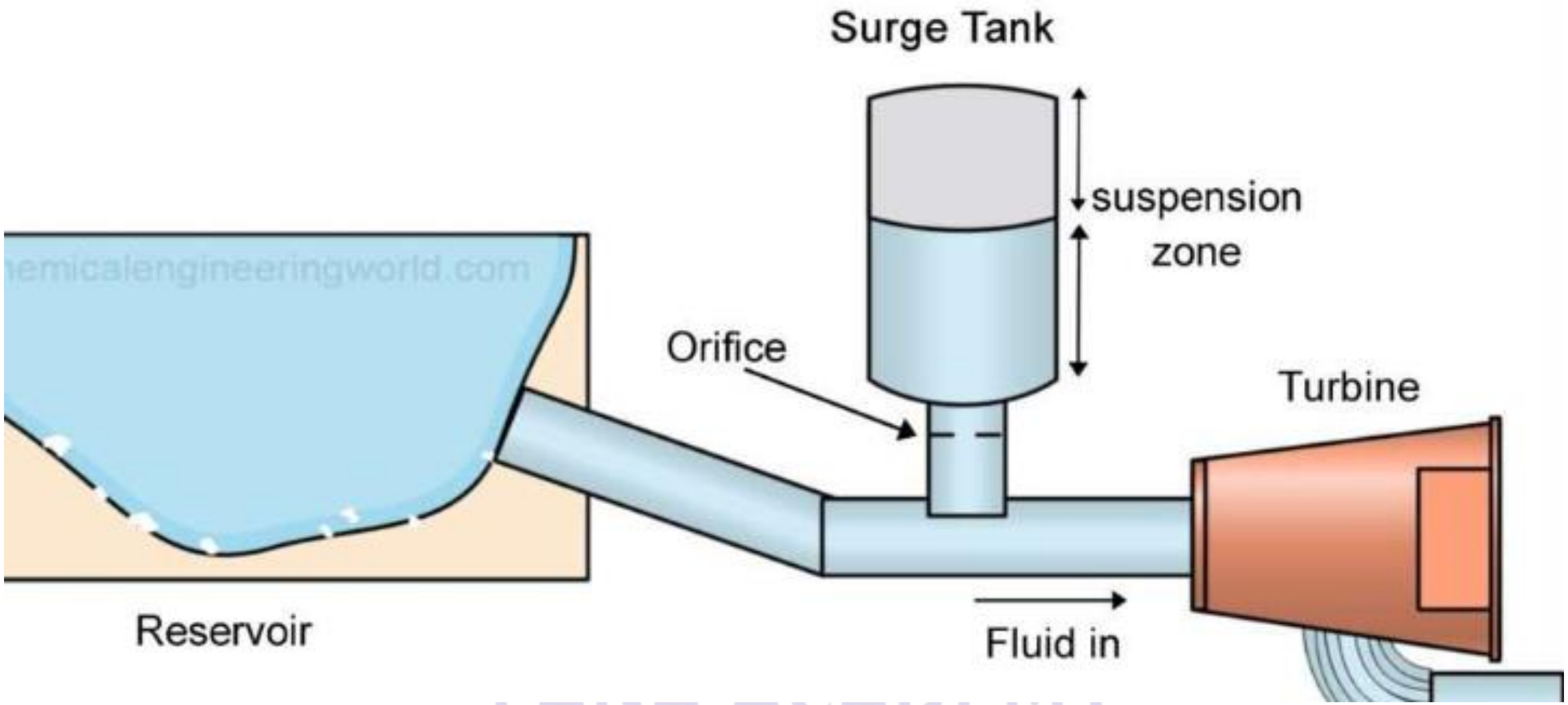
A_{st} = area of surge tank,

A_t = area of tunnel,

h_f = head loss in tunnel ,

D_t = tunnel diameter,

f = friction factor for tunnel


Surge Tank
suspension zone
Orifice
Turbine
Reservoir
Fluid in
emicalengineeringworld.com

8.5.4 Design of Penstock/Pressure Shaft

Penstock:

- Penstocks are designed to carry water from surge tank or to the turbines with the least possible loss of head consistent with the overall economy of the project.
- These are pressurized water conduits which convey water to the turbines from free water surfaces from fore bay/surge tank/reservoir to turbine unit.
- The steel pipe are mostly used in penstock, although reinforced concrete pipe, HDPE penstocks have also been built for low head HP project
- Thickness is determined considering hoop stress (PD/2t) and balancing it with allowable stress of material.

8.5.4 Design of Penstock/Pressure Shaft

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Determination of wall thickness of Penstock Pipe

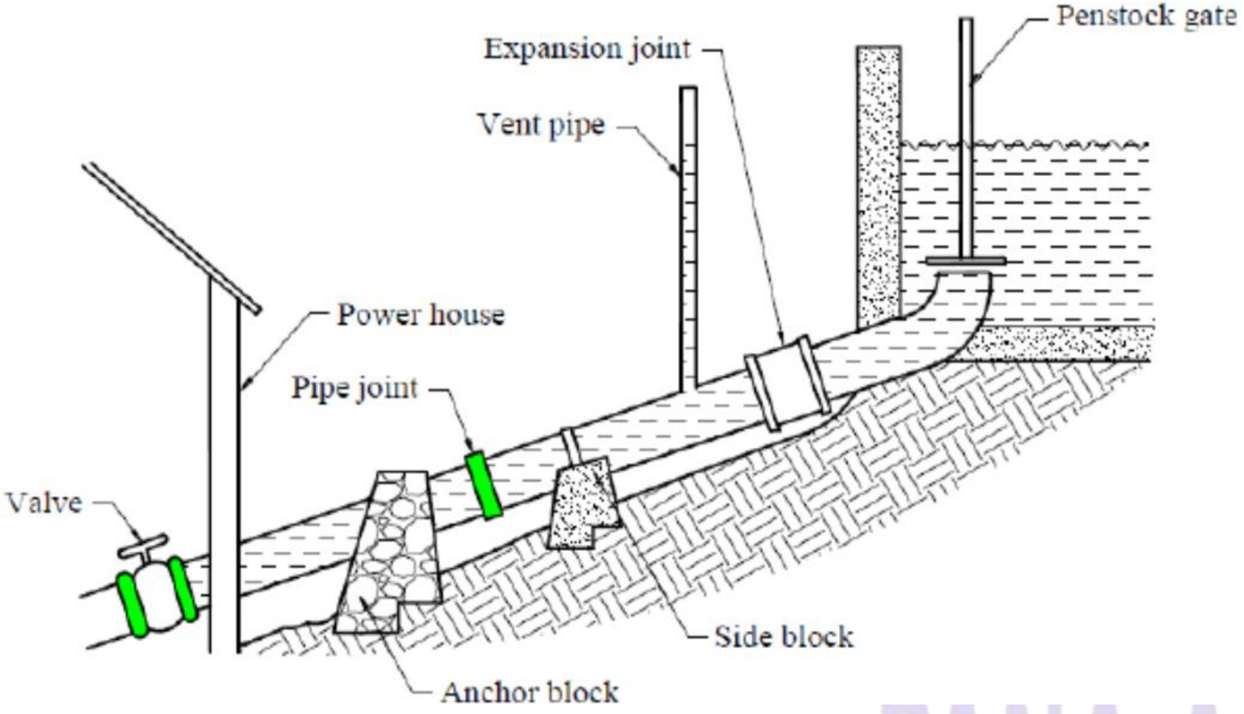
Wall thickness of the pipe materials depends on the pipe materials, its ultimate tensile strength (hoop stress) and the operating pressure including the water hammer pressure.

Thickness of penstock pipe is given by (ASME recommendation)

$$t_{cm} = \frac{P_{kg/cm^2} \times R_{cm}}{\sigma_{kg/cm^2} \times \eta - 0.6 \times P} + 0.15$$

$p \rightarrow$ Internal pressure in kg/cm^2
$R \rightarrow$ Radius of pipe in cm
$\sigma_a \rightarrow$ allowable stress in kg/cm^2
$\eta \rightarrow$ welding efficiency (0.85 to 0.9)
$t \rightarrow$ Thickness of pipe in cm.

8.5.4 Design of Penstock/Pressure Shaft



8.5.4 Design of Penstock/Pressure Shaft

- **Economical Diameter of penstock(penstock Optimization)**

  -the optimum diameter where the cost is minimum.

  Methods:

  1)Empirical Method

  2)Graphical Method

  3)Analytical Method

  $D=(5B/2A)^{1/7}$ where,

  Total cost= AD^2

  Total Revenue= B/D^5

  Head Loss in penstock (hf)= $fLV^2/2gD$ OR $8fLQ^2/\pi^2 gD^5$

8.5.4 Design of Penstock/Pressure Shaft

1) Empirical Method:

i) Sarkaria Formula

$D_{eco} = 0.62*P^{0.35} / H^{0.65}$, where, P = Power in HP (1hp=0.746kw), H = head in m

(ii) USBR Method

$V_{eco} = 0.125* \sqrt{2gH}$, $Q = A*V = \pi D^2/4 * V$,

So, $D_{eco} = \sqrt{4Q/\pi V_{eco}}$

(iii) Design guideline by JNN

$D_{eco} = (5.2*Q^3 / H)^{1/7}$

8.5.5 Hydraulic Transient/ Hammer (Water Hammer)

Water Hammer:

- The phenomenon of excessive rise of pressure in closed conduit due to destruction of momentum of fast moving liquid in the form of wave with knocking sound is called water- hammering and wave is called water hammer.

Causes:

- valve operation,
- power failure,
- start or shut down of pump,
- fluctuation in power demand,
- mechanical failure of control device

8.5.5 Hydraulic Transient (Water Hammer)

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Effects:

- High pressure fluctuation,
- Rupture of pipe,
- High thickness in the penstock pipe leading to costlier design

- Two approach for water hammer analysis:
  - Rigid water column theory
  - Elastic water column theory

8.5.6 Hydrodynamic Pressure Calculation

The pressure wave velocity due to water hammer is given as:

c) $$V_c = \sqrt{\frac{\frac{K}{\rho}}{1+\frac{D*K}{t*E}}}$$

K = Bulk Modulus of elasticity

ρ = density of water, D = Pipe diameter,

t = pipe wall thickness

E = Elastic Modulus (Young's Modulus) of pipe

8.5.6 Hydrodynamic Pressure Calculation

PANA ACADEMY

- *T = Closing time of Valve, Tc = Time taken by wave for a complete cycle*
- **Critical time of closure (T_c) = 2L/Vc**

where, L = Length of pipe, Vc= Pressure wave velocity

  - $T > T_c$, Then gradual closure or Slow Closure condition
  - $T \leq T_c$, Then Rapid closure condition

1. Rigid water column theory

When $T > T_c$, then the condition is gradual closure; use Rigid Water Column Theory, RWCT i.e.

Velocity of wave (Vc) for Rigid condition

For Rigid condition, $E \rightarrow \infty$, $DK/tE \rightarrow 0$

i) $Vc = \sqrt{\frac{K}{\rho}}$

ii) $Pw = \rho * Vo * Vc$

8.5.6 Hydrodynamic Pressure Calculation

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2) Elastic water column theory

If $T <= T_c$, it is said to be rapid closure condition

a) $P_w = \rho * Vo * Vc$, P_w = Water hammer presssure

V_o = Steady state flow velocity in penstock,

V_c = Velocity of wave, ρ = density of water

$$V_o = \frac{Q_d}{A_p}$$

b) $$h_w = \frac{P_w}{\gamma_w} = \frac{\rho * Vc * Vo}{\rho * g} = \frac{Vc * Vo}{g}$$

Lets move to,
Multiple Choice Questions

8.5 Multiple Choice Questions

1. Which phenomenon in a pipe flow is termed as water hammer?
(a) The rise of negative pressure
(b) The zero pressure in pipe flow
(c) Rise of pressure due to gradual closure of valve
(d) Sudden rise of pressure in a long pipe due to sudden closure of valve

2. The function of a surge tank is
(a) Smoothen the flow
(b) act as a reservoir for emergency conditions
(c) Avoid flow in reverse direction
(d) relieve the pipe line of excessive pressure transients oR Relieve pressure due to water hammer

8.5 Multiple Choice Questions

3. Penstocks are made up of _____________
   a) Steel
   b) Cast iron
   c) Mild steel
   d) Wrought iron

4. The phenomenon of formation of vapor bubbles and sudden collapsing of the vapor bubbles in the penstock is called as

(a) Cavitations

(b) governing

(c) Vaporization

(d) None of above

Note **Cavitation** includes the formation of vapour bubbles of the flowing liquid and collapsing of the vapour bubbles

8.5 Multiple Choice Questions

5. Which statement about surge tank is wrong?

a) Ideal location of surge tank is at the turbine inlet

b) A decrease in load demands cause a rise in water level in surge tank

c) Surge tanks are totally closed to avoid entry of unwanted objects to penstock

d) Surge tanks are installed to reduce harm effects of water hammer phenomenon

6. Penstock in a hydroelectric power plant is

a) a pipe connected to runner outlet

b) nozzle that release high pressure water on turbine blades

c) a conduit connecting forebay to scroll case of turbine

d) a pipe connecting surge tank to dam

8.5 Multiple Choice Questions

7. Cavitations usually occurs due to the changes in ________
   a) Pressure
   b) Temperature
   c) Volume
   d) Heat

8. If 'D' is the diameter of tunnel in meters, then the thickness of lining in mm, as per the empirical formula is given by
   a. 42 D
   b. 82 D
   c. 104 D
   d. 124 D

8.5 Multiple Choice Questions

9. The method of draining in the tunnels, is generally known as
   a. Fore drainage
   b. dewatering
   c. permanent drainage
   d. All of the above.

10. Drift method of tunneling is to construct tunnel in

    a. soft ground
    b. Rock
    c. self supporting grounds
    d. Broken grounds

8.5 Multiple Choice Questions

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11. Which one of the following statements is not correct for heading and benching method of tunnelling ?

    a. Drilling and mucking can be done simultaneously

    b. Benching provides a plateform for working on heading

    c. Removal of muck from the heading is very easy

    c. None of these.

12. Which element of hydroelectric power plant prevents the penstock from water hammer phenomenon?

    a) Valves and Gates

    b) Draft tubes

    c) Spillway

    d) Surge Tank

8.5 Multiple Choice Questions

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13. The most suitable soil for compressed air tunneling is
    a. silt
    b. sand
    c. clay
    d. Gravel

Explanation: Compressed air tunnelling: It is the most advance method for tunneling used in soft soil with low bearing capacity like clay

14. Forepoling method is generally adopted for tunnelling in :
    a. soft ground
    b. firm ground
    c. running ground
    d. None of these.

8.5 Multiple Choice Questions

PANA ACADEMY

15. The surge tank controls the water when the load on the turbine is

a) Equal
b) Decreased
c) Increased
d) Not present

16. What parameter is commonly used to determine the diameter of a hydropower tunnel?

a. Water pressure in the tunnel
b. Length of the tunnel
c. Flow rate of water
d. Number of turbines in the powerhouse

8.5 Multiple Choice Questions

17. Whenever closed conduits are used in a hydroelectric power plant, ___________ is/are used to limit the abnormal pressure in the conduit.
    a. Penstocks
    b. surge tank
    c. headworks
    d. spillways

18. Water hammer is developed in a
    a. penstock.
    b. draft tube.
    c. surge tank.
    d. turbine.

8.5 Multiple Choice Questions

19. In case of drift method of tunnelling, the drift may be excavated at
    a. the centre
    b. the top
    c. the side
    d. All of the above.

20. A tunnel is found more advantageous as compared to the alternate routes because it:
    a. remains free from snow
    b. reduces the cost by reducing the route distance
    c. reduces the maintenance cost
    d. avoids interference with surface rights
    e. All the above.

8.5 Multiple Choice Questions

21. To attain the required shape of the tunnel section, we use:
    a. Easers
    b. Trimmers
    c. Cut holes
    d. Chisels

22. Which one section of tunnel is suitable where the tunnel is subjected to high internal pressure, but does not have good quality of rock and/or adequate rock cover around it
    a) Circular section
    b) D-Section
    c) Horse-Shoe section
    d) Egg shaped section

8.5 Multiple Choice Questions

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23. Head loss due to friction in water flow through penstock can be minimized by

a) Decrease diameter of penstock
b) Increase dia of penstock
c) Increase length of penstock
d) Increase velocity of penstock

24. In a hydroelectric power plant, where is the penstock used?

a) Between dam and the turbine
b) Between turbine and discharge drain
c) Turbine and heat exchanger
d) Heat exchanger and fluid pump

8.5 Multiple Choice Questions

25. Which among the following is used as a regulating reservoir?

a) Reservoir

b) Spillways

c) Forebay

d) Penstock

26. Which of the following element of hydroelectric power plant prevents the penstock from water hammer phenomenon?

a) Surge Tank

b) Draft tubes

c) Spillway

d) Valves and Gates

8.5 Multiple Choice Questions

27. A penstock is 300 mtr long. Pressure wave travels in it with velocity of 1500 m/s. If the turbine gates are closed uniformly and completely in a period of 4.5 seconds, then it is called:

a) Rapid Closure

b) Slow Closure

c) Sudden Closure

d) Uniform Closure

28. A penstock pipe of 10m diameter carries water under a pressure head of 100 m. If the wall thickness is 9 mm, what is the tensile stress in the pipe wall in MPa?

a)2725

b)545

c)272

d)1090

Note: Tensile stress in the pipe wall = Circumferential stress in pipe wall = Pd/2t Where,

P= Y_wH, t= wall thickness of pipe, d= diameter of pipe, H= Residual head

THANK YOU