Airport Engineering

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(This Module shall only be Used for Educational Purpose.)

AIRPORT ENGINEERING

INDEX

1 AIRPORT

1.1. Introduction

Airport i.e. an area which i.e. to be regularly used for landing and take off of airport.

Classification

- As per Federal Aviation Agency (FAA)
  - Non-primary Airports
    - Passengers < 10,000/yr
  - Primary Airports
    - Passengers < 10,000/yr
- As per International Civil Aviation Organisation (ICAO)
  - Based on of Runway length
    - A to E
    - A → longest
      E → shortest runway
  - Based on ESWL and Type pressure
    - 1 to 7
    - 1 → max pressure
      7 → min pressure

1.1.1. Aircraft Components

(i) Engine:

(a) Piston Engine: For moderate speeds at low altitudes

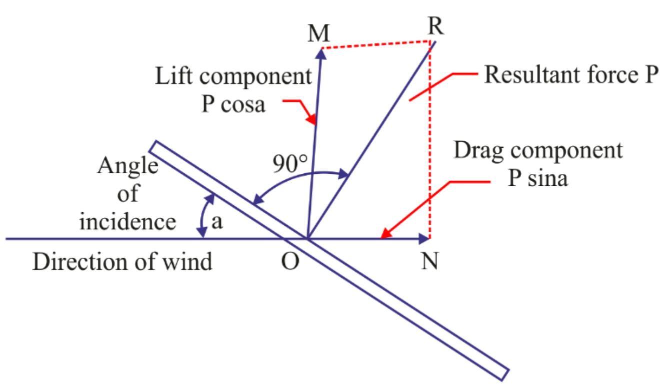
(b) Turbo Jet: For Higher altitude and greater temperature difference.

(c) Turbo Prop: At low as well as high altitude.

(d) Ram Jet: No moving parts, operates at high speed

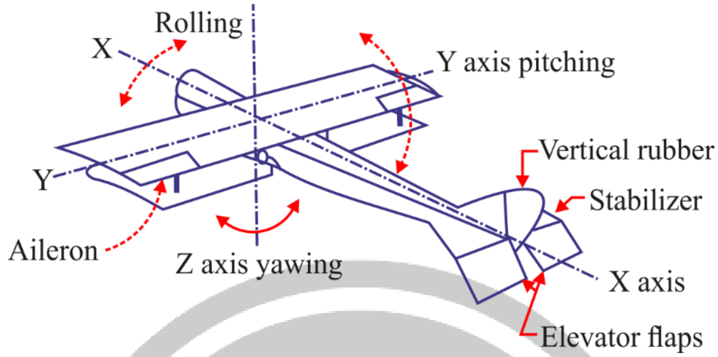
(e) Rocket Engine: No limit on altitude

(ii) Wings:



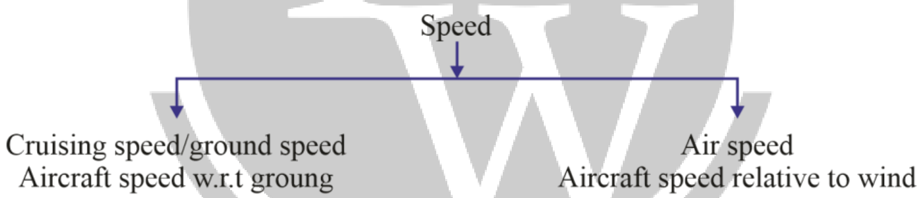
(iii) Three Controls:

Controller	Used for
Elevator	Pitching
Rudder	Yawning
Aileron	Rolling



(iv) Fuselage

- It's the main body part of aircraft
- **Minimum Turning Radius:** Distance of farther wing tip from the centre line of rotation.
- Minimum circular radius: Minimum radius with which the aircraft can turn in space.



Maximum Ramp Weight > Maximum Take Off Weight > Maximum Landing Weight

- **Jet Blast:** Cement concrete pavement is provided. at least at the touch down portion as the bituminous pavement gets affected by the jet blasts.
- **Noise:** Noise foot print recommended is 1 km^2 for 90 *PN dB* and 8 km^2 for 80 *PN dB* (Perceived Noise decibel).

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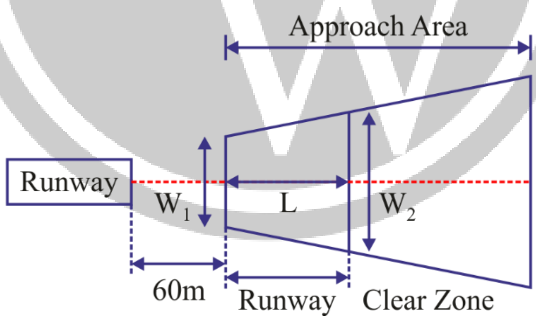
2 AIRPORT PLANNING

2.1. Introduction

- **Factors affecting Airport site Selection:** Airport use, proximity to other airports, Topography of area, obstruction and visibility, wind (direction, duration and intensity), Noise, Future development, Drainage and soil conditions.
- **Survey's for site Selection:** Traffic survey, metrological survey, Topographical survey, soil survey, material survey. Drainage survey.

Note: Most desirable soil with natural drainage conditions contains large amount of sand and gravels.

- **Zoning Laws:** Laws made in order to prevent future development of obstructions in the vicinity of airport and turning and taking off direction of aircraft.
- **Approach Zone:** Wide clearance area required on either side of runway along the direction of landing or take off of airport.



	w_1	w_2	L
Non-Instrument Runway	150 m	270 m	600 m
Instrument Runway	300 m	525 m	750 m

Note: Instrument Runway is equipped with device permitting the landing under condition of poor visibility.

- **Clear Zone:** The inner most portion of approach zone, which is the most critical portion from obstruction point of view.
- **Turning Zone:** The area of airport other than approach zone which is used for turning operation of aircraft. Any object located 4.5 km from runway reference point shall be considered as an obstruction for aircraft turning operation if its height is more than 51m.

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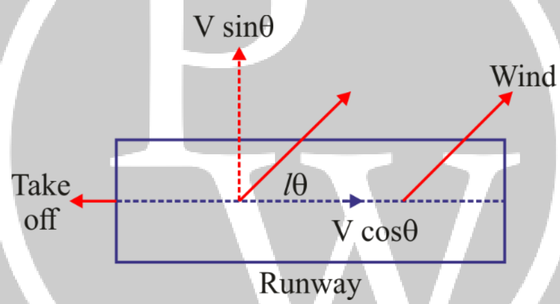
3 RUNWAY DESIGN

3.1. Runway Design

Runway Orientation

It is oriented such that the direction of wind is opposite to the direction of landing and take off. If landing and take off operation are done along the wind direction then longer runway will be required.

Cross-Wind Component



$V \sin\theta$ = Cross Wind Component

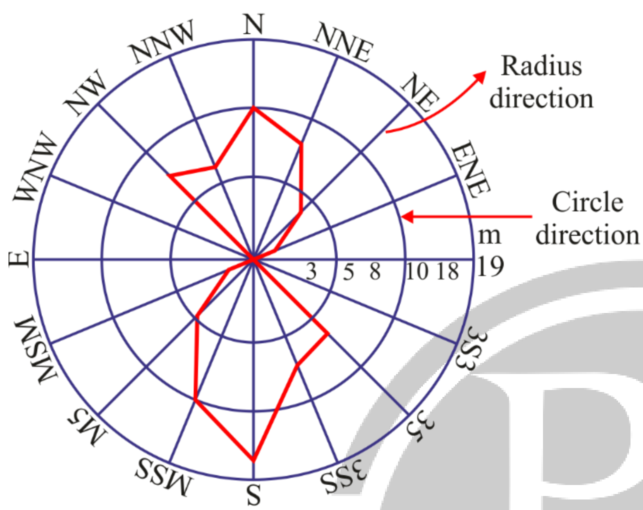
Type of aircraft	Permissible Limit of Cross Wind Component
Small aircraft	15 kmph
Mixed traffic	25 kmph
Big aircraft	35 kmph

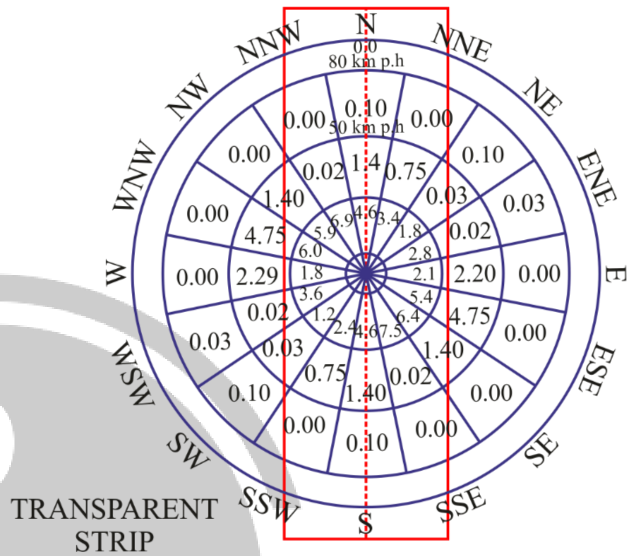
- **Wind Coverage:** The percentage of time in a year during which cross wind component is with in the permissible limits.
- **Wind rose diagram:** It's the graphical representation of direction, duration and intensity of wind. The wind data of atleast 5 years and preferably 10 years is needed for airport deigning.

Type

Type-1
Showing direction and duration

Type-2
Showing direction, duration & intensity





Radius → Wind Direction
Circle → Duration of Wind

Radius → Wind Direction
Circle → Wind Intensity
Value Entered → Wind Coverage

Note: Calm period ie the percentage of time during which intensity is less than 6.4 kmph.

3.2. Basic Runway Length

Length of runway under following assumed conditions

(i) Airport at sea level

(ii) Temperature at airport is 15°C (standard)

(iii) Runway is levelled in longitudinal direction.

(iv) No wind blowing on runway.

(v) Aircraft is loaded at its full capacity.

(vi) There is no wind blowing enroute to destination

(vii) Enroute temperature is standard.

Corrections in Runway Length

(i) Correction for Elevation:

$$L' = L \times \frac{7}{100} \times \frac{E}{300}$$

$L_1 = L + L'$
$E \rightarrow$ Elevation from MSL (m)
$L \rightarrow$ Basic runway length
$L' \rightarrow$ Correction due to elevation
$L_1 \rightarrow$ Corrected length

(ii) Correction for Temperature:

$$\text{Standard temp} = 15 - 0.0065\,(E)$$

$$\text{Reference temp} = T_a + 1/3(T_m - T_a)$$

T_a = Monthly mean of average daily temperature of hottest month

T_m = Monthly mean of maximum daily temperature.

ΔT = Reference temp - Standard temp.

$$L'' = L_1\,\Delta T \times \frac{1}{100}$$

$L_2 = L_1 + L''$

L'' = Correction due to Temperature

L_2 = Corrected Length after Temperature Correction.

Cheek: $\frac{L_2 - L}{L} \times 100 < 35$

(iii) Correction for Gradient:

$$L''' = L_2 \times G \times \frac{20}{100}$$

$L_3 = L_2 + L'''$
G = Gradient in%
L''' = Correction due to Gradient
L_3 = Final Runway Length

Note: ICAO does not recommend any gradient correction.

3.3. Geometric design of Runway

(i) Runway length: Actual runway length (Ls) depends upon elevation, temperature and gradient.

(ii) Runway width: Recommended range is 10 m to 45 m. Typical aircraft traffic is concentrated at central 24 m.

(iii) Width of safety area: Runway width + shoulder on either side + area cleared, graded and drained.

As per CAO, for Non-Instrumental runway minimum width of safety area

(a) for A, B, C type = 150 m

(b) for D and E type = 78 m

For instrumental runway its 300 m

(iv) Length of Safety Area: 60 m beyond runway at both ends

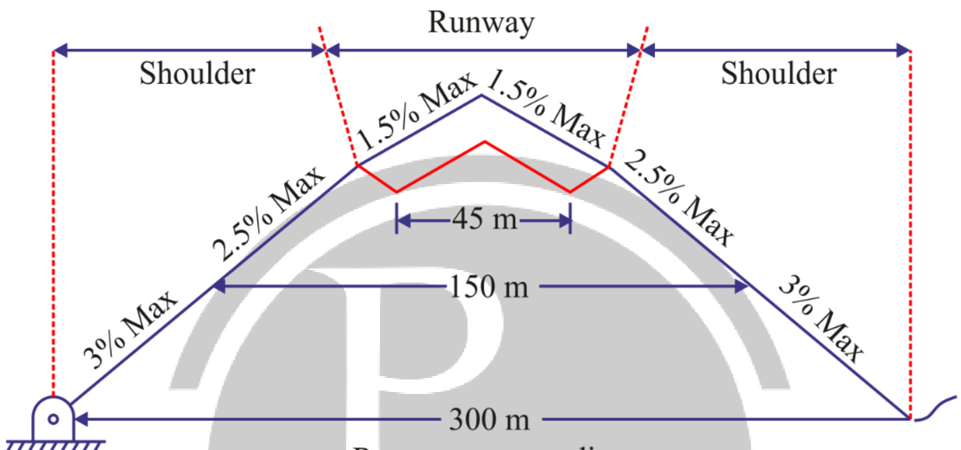
(v) Transverse Gradient: for proper drainage. AS per ICAO

(a) For A, B, C type = Max. Value 1.5%

(b) For D and E type = Max. Value 2%

While minimum value is 0.5% in both above cases

Note: ICAO recommends that upto 75 m from centre its maximum gradient can be 5%.



Runway cross-sedion

(iv) Longitudinal gradient

(a) For A, B, C type = 1.5% max.

(b) For D, E type = 2% max.

(vii) Effective gradient

(a) For A, B, C type = 1% max.

(b) For D, E type = 2% max.

(vii) Rate of change of longitudinal gradient

(a) For A and B type = 0.1% per 30 m length

(b) For C type = 0.2% per 30 m length

(c) For D, E type = 0.4% per 30 m length

(viii) Sight distance:

For A, B, C type of airport any two points having 3m above surface (2.lm above surface for D and E type) of runway should be mutually visible from a distance equal to half of runway length.

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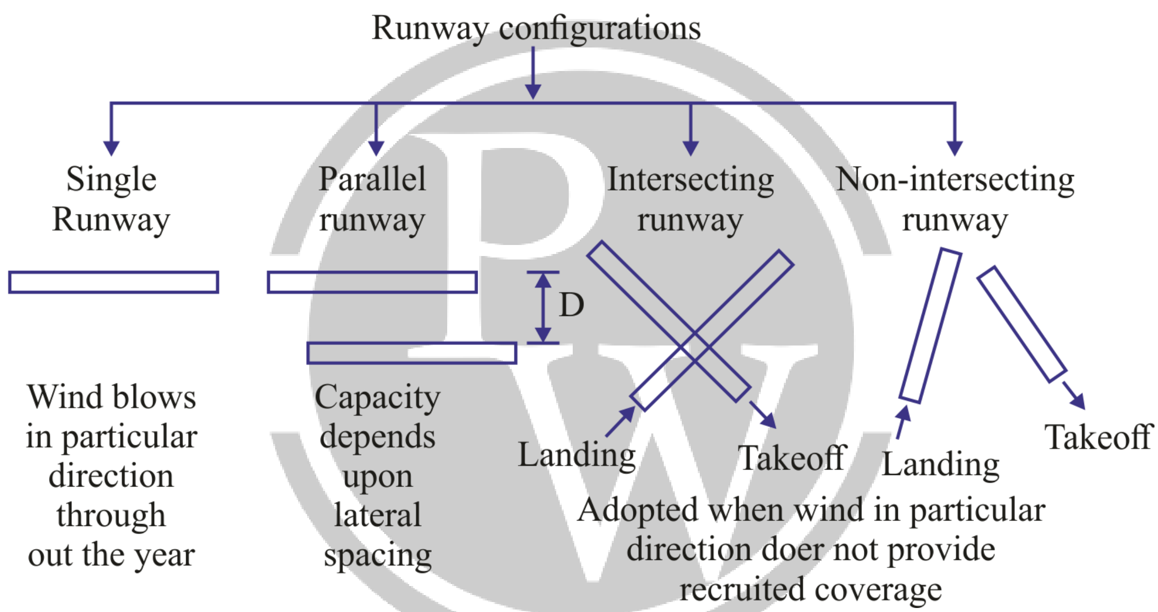
4 AIRPORT CAPACITY

4.1. Introduction

Airport Capacity: No. of movements (landing or taking off operation) of aircraft which the airport can safely handle within an hour.



Runway Capacity: (Operations/Hr or Operations/Year)

It's the ability of a runway system to accommodate aircraft landing take off's. Factors affecting runway capacity are: Air traffic control, demand characteristics, Environmental factors, layout and design of runway system.

Gate Capacity: It's an ability of specified no of gates to accommodate aircraft loading and unloading operations under conditions of continuous demand whereas gate may be defined as aircraft parking space adjacent to terminal building for loading and unloading of passengers. Single Gate

Gate Capacity for a site = No of aircrafts/minute/gate

$$\text{Capacity}_{\text{Single Gate}}\left(C_{Sg}\right) = \frac{1}{\text{Weighted Service Time}}$$

Capacity of all gates $\boxed{C = G\, C_{Sg}}$

Capacity of gate system = min all $\left[\frac{G_i}{T_i\ M_i}\right]$

G_i = No of gates that can accommodate aircraft of class i

T_i = Mean gate occupancy time of aircraft of class i

M_i = Fraction of aircraft of class i demanding service.

Taxiway Capacity

It directly affects the runway and gate capacity. It depends on runway operation rate, aircraft mix and location of exit taxiway.

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5 TAXIWAY DESIGN

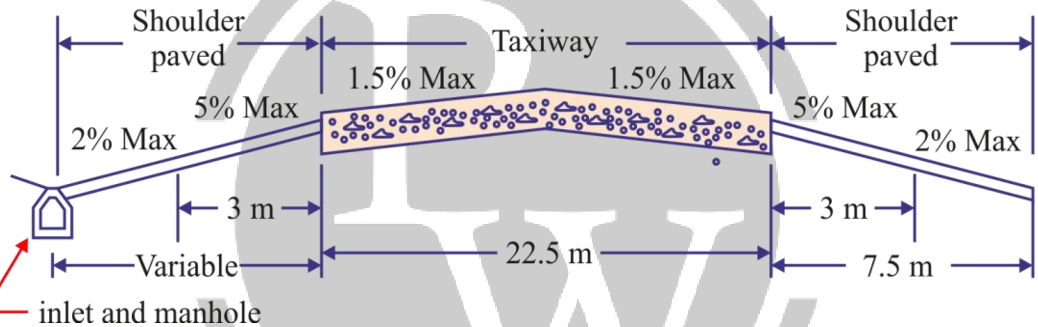
5.1. Introduction

It provides access to the aircraft from run way to loading apron or service hanger and back.

Factor's effecting geometric design of taxiway:

(i) Length of taxiway: As short as possible

(ii) Width of taxiway: 22.5 m to 7.5m



(iii) Longitudinal gradient:

(a) **for B type:** max 1.5%

(b) **for C, D, E type:** max 3%

(iii) Transverse gradient: for A and B type its max value is 1.5% and minimum is 0.6%

(υ) **Rate of change of longitudinal gradient**

(a) for A, B, C type = 1% in30%

(b) for D, E type = 1.2% in30%

(vi) Sight distance:

(a) **for B, C type:** Surface should be visible from 3m height at 300 m distance

(b) **for D, E type:** Surface should be visible from 2.1m height at 250 m distance

(vii) Turning radius:

(a) Radius of the curve $R = \frac{V^2}{125f}$

R = radius (m)
V = velocity (km.ph)
f = Transverse friction coefficient (0.13)

(b) By Horonjeff's Equation

$$R = \frac{0.388\,W^2}{\frac{T}{2} - S}$$

W = Wheel base of aircraft in m (16 m – 18 m)

T = Width of taxiway pavement (std = 22.5 m)

S = Distance between midway point of the main gear and edge of taxiway pavement in m.

$$S = 6 + \frac{Tread\ of\ main\ loading\ gear}{2}$$

(c) Absolute minimum turning radius regardless of speed

1. for subsonic jet = 120 m
2. for supersonic jet = 180 m

Minimum radius of taxiway will be the maximum of a, b, c discussed above.

Exit Taxiway

Taxiway located at various points such that landing aircraft leaves the runway as early as possible. Location of taxiway depends upon

(i) Number of exit taxiway

(ii) Exit speed

(iii) Weather condition

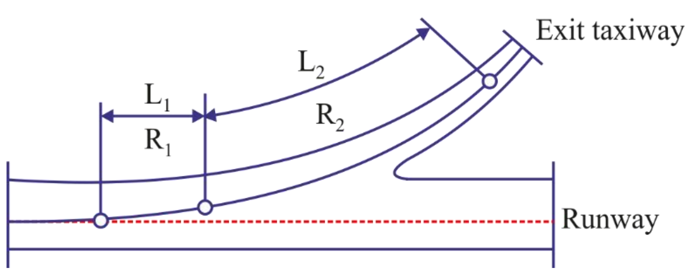
(iv) Topographic feature.

Design of Exit Taxi Way:

At high tum off speeds of 65 kmph to 95kmph, a compound curve is necessary to minimise the tire wear on the nose gear so, the main radius curve R_2 should be preceded by a larger radius curve R_1 as shown. Aircraft path approximates **a spiral.**
Stopping Distance

$$L_1 = \frac{V^3}{45.5\ CR_2} \quad C \simeq 0.39$$

$$Stopping\ Distance = \frac{V^3}{25.5\ d} \quad d = Deceleration$$



Apron: Paved area for parking of aircraft as well as for loading and unloading the passenger and cargo.

Size of Apron Depends Upon:

(i) **Size of loading area:** i.e. gate size

(ii) **Number of gate position:** It's the runway capacity in unit of movement per hour

$$\text{Number of Gate Position} = \frac{\text{Capacity of Runway}}{60 \times 2} \times \text{Average Gate Occupancy Time}$$

(iii) **Aircraft parking system:**

(a) Frontal system

(b) Open area system

(c) Finger system

(d) Satellite system

Note: Holding apron is the storage area for waiting of aircraft before take off generally provided at busy airport.

Banger: It's the covered area for repair and servicing the aircraft.

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6 WATER-TRANSPORTATION

6.1. Introduction

- Water-transportation
  - Inland water transportation through river canal or lakes
  - Ocean transportation

Note: Water transportation has higher load carrying capacity but it's slow and risky (due to storms and hurricanes).

Harbour

A partially enclosed protected water area to provide safe and suitable accommodation for vessels, seeking refuge, supplies, refuelling, repair or transfer of cargo.

- Classification
  - On basis of protection of head
    - Natural harbour
    - Semi natural harbour
    - Artificial harbour
  - On the basis of utility
    - Refuse
    - Commercial
    - Fishing
    - Military
  - On basis of location
    - Sea or ocean harbour
    - River or estuary
    - Canal harbour
    - Lake harbour

Selection of Site:

(i) An easy accessibility via wide and straight approach.

(ii) Wide entrance for manoeuvring.

(iii) Deep water bay.

(iv) Rock bottom locations should be avoided.

6.2. Harbour Layout Elements

(i) **Harbour Size:** Minimum harbour area is equal to the space required for the dock plus the turning basin in front of them.

(ii) **Harbour Depth:**

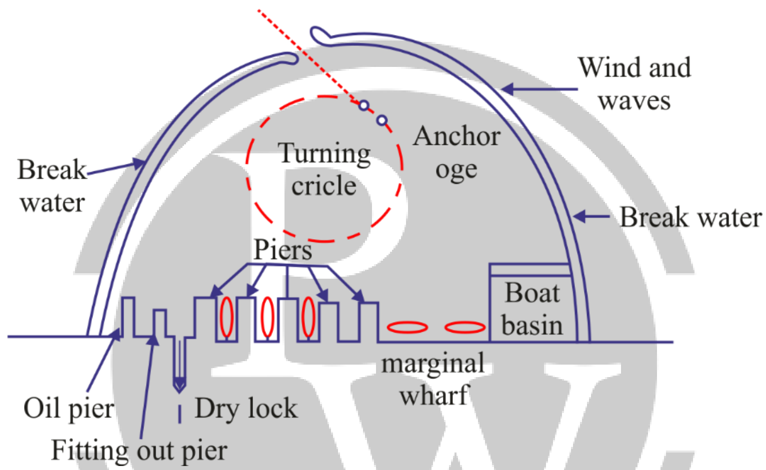
$$D = D' + D'' = \frac{H}{3}$$

D = Channel depth

D' = Draft of the largest ship

D'' = Allowance for squat of the moving ship

H = Height of the storm wave, crest to trough.



max . harbour depth = Loaded draft + 1.2 m (when bottom is soft)

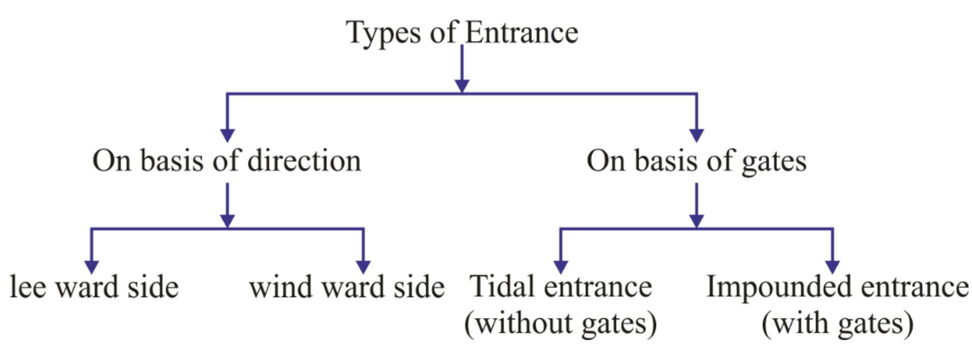
max . harbour depth = Loaded draft + 1.8m (when bottom is rock)

> **Note:** Loaded draft = Submerged depth of ship.

(iii) **Turning basin:** It's minimum radius is twice the length of ship.

(iv) **Anchorage Area:** Area of the circle whose radius is = (4 x depth of water) + (length of ship) + (safe clearance to adjacent ship)

(v) **Barbour Entrance Channel:** It connects the harbour to the deep sea The radius of the curve should be larger than five times the length of largest expected ship.



Sounding

Measurement of depth below the water surface. Instruments used are

(i) Fathometer (Echo-Sounding): Used where depth of water is too much. Main parts of an echo sounding apparatus are

(a) Transmitting and receiving oscillators

(b) Recorder unit.

(c) Transmitter/power unit.

(ii) Sextant: To find the distance of an observer in the sea. Also used to take simultaneous observations of two moving objects.

(iii) Station Pointer: It's a three-armed protractor and consists of graduated circle with a fixed arm and two movable arms on either side.

(iv) Hi-fix: A high precision light weight electronic position fixing system.

7 TIDES AND SHORE PROTECTION WORKS

7.1. Introduction

Tide: A natural phenomenon by which level of ocean water undergoes perodic rise and fall.

Note: The influence of moon is greater than sun.

Mean sea level is the based on analysis of tidal sea level fluctuations over 19 years.

Lunar Day: Time taken by moon to complete one revolution around earth.

Note: Lunar day is 50 minutes longer than solar day.

Spring Tides: Highest tides when the generating forces due to moon and sun are additives.

Neap Tides: When lines connecting the earth with sun and earth with moon form a right angle

Tidal Range: Level difference between high level to low level of water for a particular tide.

$$\text{Tidal force due to sun} = 0.45 \times \text{Tidal force due to moon}$$

Wind: It’s speed is expressed in **knots** (1043 kmph). It's the length of one minute of area of a meridian which varies with different latitudes It causes waves inopen sea.

Wave: It is generated by transfer of energy from air which is moving over the water surface.

(i) $\text{Height of wave (m)} = 0.34\sqrt{F}$ By Stevenson

F = Fetch (Surface giving rise to waves) in km

(ii) $\text{Length of wave (m)} = \frac{t^2}{2\pi}g = 1.56\,t^2$ By Bertin's Formulae

t = Time Period (in see)

Note: Distance between adjacent crest of a wave gives its length.

(iii) Significant wave height (Hs) = Average height of 1/3highest waves.

(iv) Average height (HA) = 0.6 Hs (v)Highest wave H,,_ = 1.87 H8

Note: **Clapotis:** It is a phenomenon by which waves strikes a vertical break water in dep water, it is reflected back and on meeting another advancing wave of similar amplitude will merge and rise vertical in a wall of water.

Shore Protection Works:

(i) **OFF shore break water:** Rubble mound type structure, effective for intercepting littoral movement.

(ii) **Seawall, bulkheads and revetments:** Structures parallel to shoreline which develop a demarcating line between land and sea. Revetment is protective pavement supported by an earthwork.

(iii) **Sand dunes:** Formation along coast prevent movement of tides into the area.

(iv) **Protective or spending beaches:** Grant protection to adjacent uplands.

(v) **Groynes:** Structures or projections from the bank for trapping of littoral drift

Note: Littoral drift is the drifting of sand in a zigzag line.

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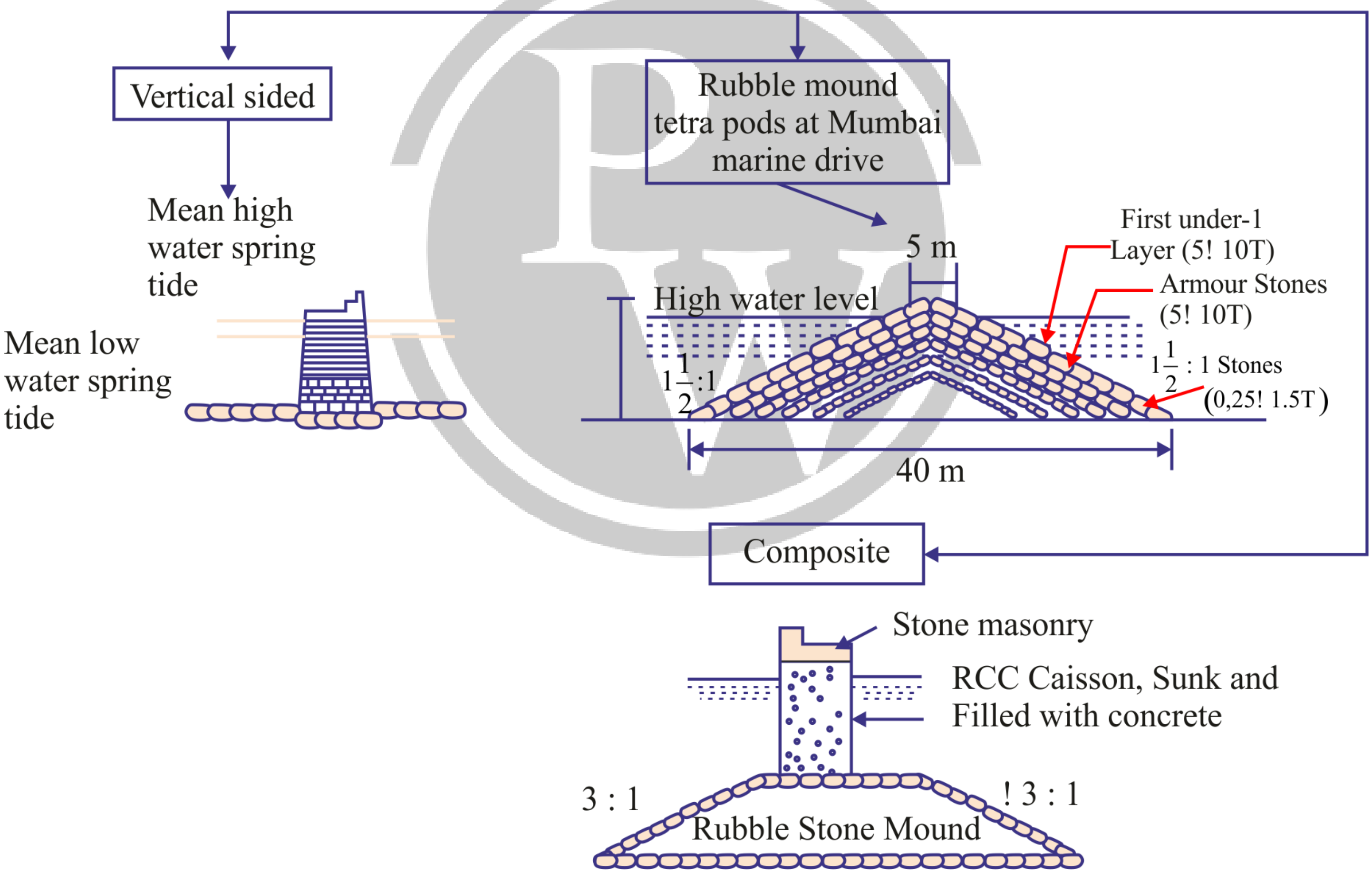
8 BREAK WATERS

8.1. Introduction

It is a structure constructed with the purpose of protecting an area from the effect of sea waves so that ships can safely be moored in that area. Break water height is kept equivalent to 1.2 to 1.25 times the height of the wave expected above the high water level.



- **Fenders:** It is the form of cushion provided on jetty face **to absorb the impact of the ship** and protect them from damage. It also prevents the ship paint from being damaged because of relative motion between dock and ship.
- **Wharf:** These are platforms at which vessels take on and discharge passenger and cargo. They are the docks that **are parallel to** the shore. Wharfs which are built parallel with the shore are called quays.

Open type wharf's
- Provided little resistance to water movement
- Decks are supported by piles or cylinder

Solid type wharf's
- Provide adequate resistance to the impact of mooring vessles
- Decks are supported by sheet piles cells, bulkhead, cribs, caisson and quay walls

> **Note:** A break water which substitutes a quay wall and which can be used as a platform for loading and unloading cargo in calm water.

Mooring dolphins
- Not designed for impact of ship

Breasting dolphins
- Designed to take impact of ship

- **Dolphins:** Used for tying up ships and for transferring cargo between ships moored along both sides of dolphin.
- **Catwalks:** Provide access to and between dolphins.
- **Jetties:** Built roughly perpendicular to the shore for maintaining an entrance channel.

9 Dock

9.1. Introduction

Dock is artificial enclosure for the reception of ships

- Harbour dock or Wet dock
  - wet docks in tidal basin
  - Enclosed wet docks
- Repair dock or Dry dock
  - Gravity dry dock
  - Marine railway dry dock or slipway
  - Lift dry dock
  - Floating type of dock

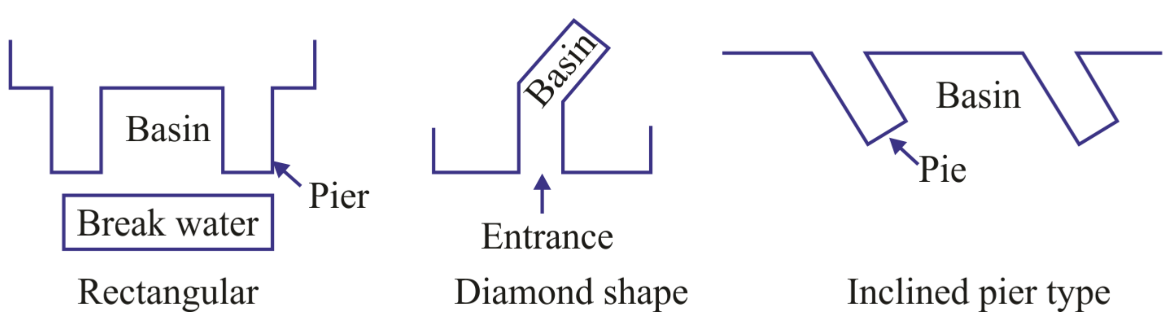
Harbour/Wet Dock

For berthing of vessels to facilitate loading and unloading of passengers.

(i) Wet docks in tidal basin, are ports on the open sea coast protected by an outlaying breakwater. Lock gates for entrance are not provided hence lot of fluctuations in water level.

(ii) In Enclosed wet docks water level is maintained by providing locks and lock gates so that cargo handing becomes convenient. It is costly.

Shapes of Dock and Basin



Repair/Dry Dock

There are used for repair of vessels.

(i) **Gravity dry dock:** Operates by admitting a vessel into the chamber, close the gate and then pumping out the water.

(ii) **Marine railway dry dock or slip:** It consists of inclined path of timber or stone upon which a series of rails are fixed and they run up from a sufficient depth of water to a required height above the high water level.

(iii) **Lift dry dock:** Platforms are lowered into and raised from water by hydraulic power applied through series of cylinders.

(iv) **Floating type of dry dock:** Its a floating vessel which can lift a ship out of water and retain it above water by means of its own buoyancy.

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10 TUNNEL ENGINEERING

10.1. Introduction

It is an engineering structure, artificial gallery, passage or roadway beneath the ground, under the bed of a stream or through a hill or mountain.

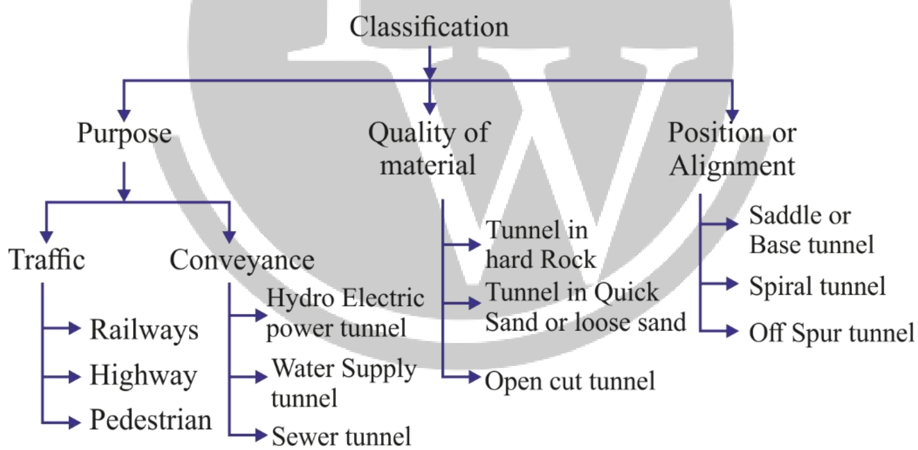
10.1.1. Advantages of Tunnel

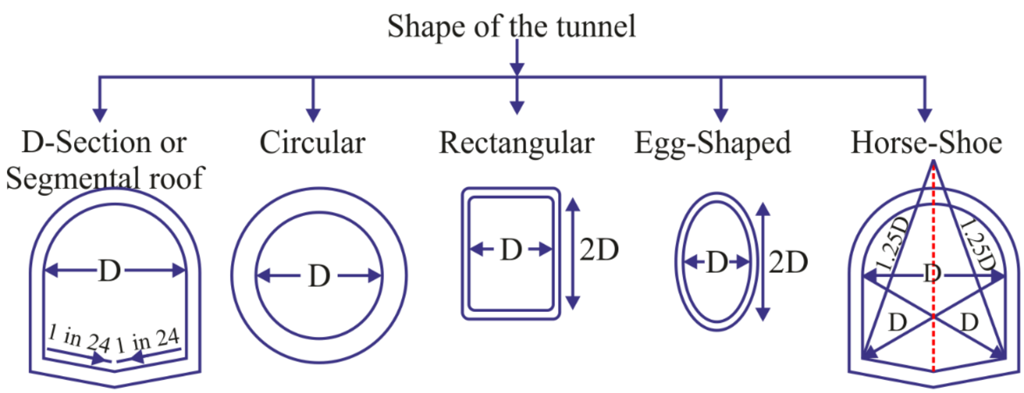
(i) For carrying public utilities like water, gas, railway lines or roads etc.

(ii) Aerial warfare and bombing of cities have given intangible values to tunnel.

(iii) Lesser maintenance and operating cost.

(iv) Cost of hauling is decreased due to lighter grades, possible in tunnels.





(a) 'D' Section (b) Circular Section (c) Rectangular Section (d) Egg. Shaped Section (e) Horse-shoe Section

(i) **In Rock tunnels**, the risk of failure or collapse caused by extremal pressure from water or loose or unstable soil conditions on tunnel lining is practically non-existent and it is then convenient to have a section with an arched roof and straight sides which is called segmental or D-section.

(ii) **Circular section** is best suited for materials without cohesion **(Quick sands)** where the pressure acts normal to the line of profile.

(iii) **Rectangular section** is suitable only in case of hard rocks.

(iv) **Egg shaped section** is used in **sewers** as it maintains required self cleansing velocity.

(v) **Horse shoe shape** is best suited for traffic purposes.

Investigations in Tunnel Construction

Information collected are:

(i) Origin os soil mass.

(ii) Hydrology in surrounding proposed tunnel site.

(iii) Presence of foul gases.

(iv) Temperature of soil nearby

(v) Location of faults, folds etc.

(vi) Bearing capacity of soil mass at proposed site.

Operations Involved in Survey

(i) Locating centre line on ground.

(ii) Providing centre line to inside tunnel.

(iii) Providing required grade at the bottom of tunnel.

(iv) Checking tunnel cross-section.

Setting of centre line

- Shot tunnels
  Theodolite with wooden stakes
- Long tunnels
  By triangulation using micrometer and transit theodolite
- Curvelinear tunnel
  (a) method of tangent offsets
  (b) method of chords and deflection angles

Shafts

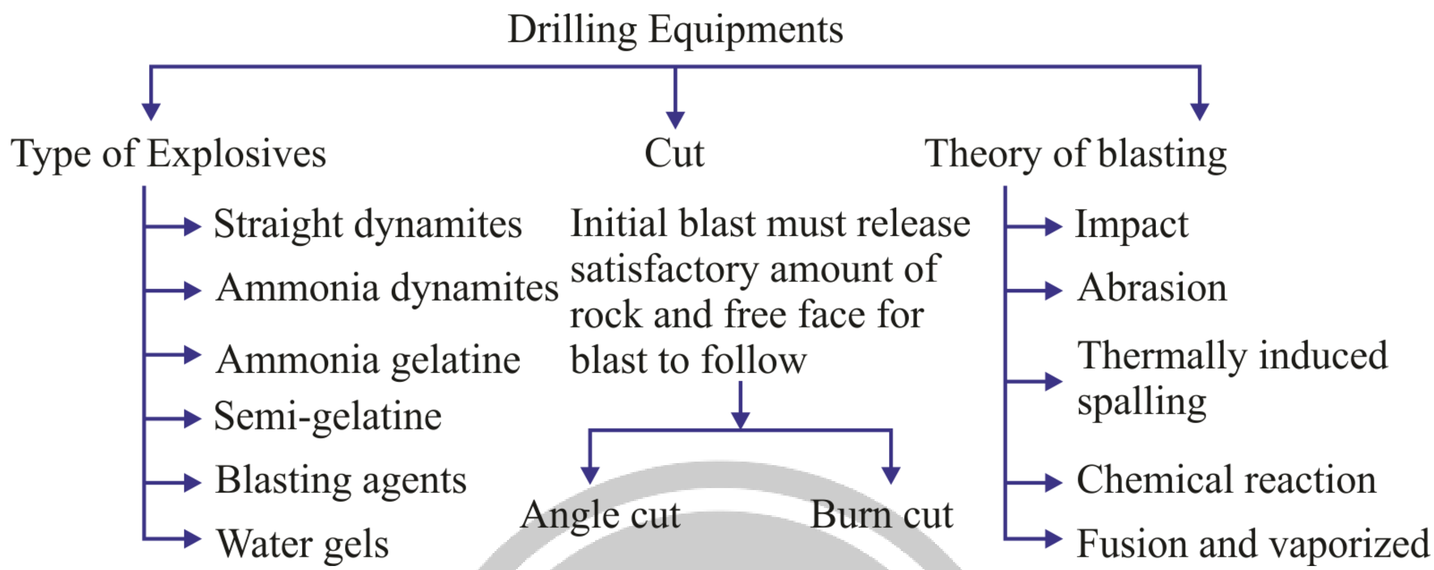
There are vertical wells sunk along the centre line of tunnel to permit excavation, removal of excavated material and to provide adequate ventilation during construction.

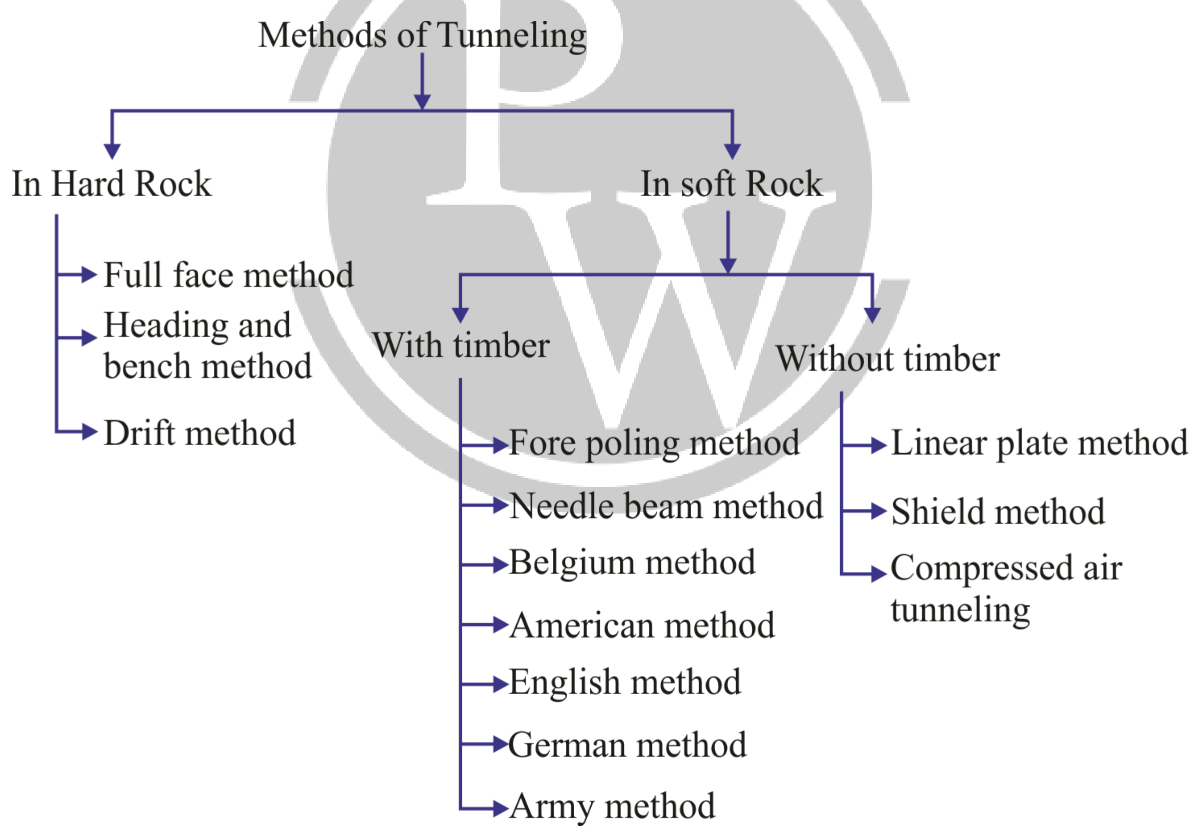
Drilling Equipments

- Percussion
  - Drills Breaks rock by impact from repeated blows
- Abrasion Drills
  - Grinds rock through abrasive effect
- Fusion piercing
  - Produces mixture of oxygen and flux bearing fuel at the end of blow pipe

Blasting

Operation performed to loosen rock so that it may be excavated or re-moved from its existing position.



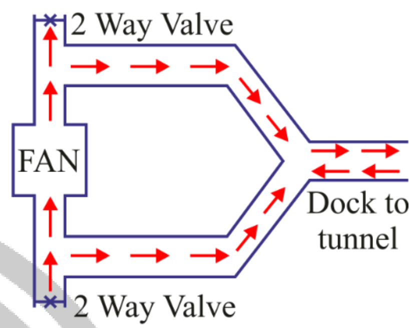


Hauling of Muck

It's the operation of loading and removing excavated or hosted materials and then dumping it at predetermined sites. It is done to make enough working room and final cleaning of bottom to place inverts. It is either done by hands or machines.

Ventilation in tunnel

- Natural Ventilation
  → due to difference in inside and outside temperature
- Mechanical Ventilation
  - Blowing
  - Exhausting
  - Combination of Blowing and exhausting



Combination of blow in and blow out

Note: Alight intensity of **260 lumens per square meter** in the working area is considered satisfactory in tunnelling operations.

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