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BGSIT

DEPARTMENT OF CIVIL ENGINEERING

Railways, Harbour, Tunneling & Airports

MODULE:1

RAILWAY PLANNING

MODES OF TRANSPORTATION

- Basic media of transportation are
  - Land
    - Roadway
    - railway
  - Water
  - Air

Rail Transport

- **Advantages of Rail transport:**
- It is a convenient mode of transport for travelling long distances.
- It is relatively faster than road transport.
- It is suitable for carrying heavy goods in large quantities over long distances.
- Its operation is less affected by adverse weathers conditions like rain, floods, fog, etc.
- **Limitations of Railway transport:**
- It is relatively expensive for carrying goods and passengers over short distances.
- It is not available in remote parts of the country.
- It provides service according to fixed time schedule and is not flexible for loading or unloading of goods at any place.
- It involves heavy losses of life as well as goods in case of accident.

Road Transport

- It is a relatively cheaper mode of transport as compared to other modes.
- Perishable goods can be transported at a faster speed by road carriers over a short distance.
- It is a flexible mode of transport as loading and unloading is possible at any destination. i.e., for travel with reference to route , direction , time and speed of travel.
- It provides door-to-door service.
- It helps people to travel and carry goods from one place to another, in places which are not connected by other means of transport like hilly areas.

Limitations of Road transport

- Due to limited carrying capacity road transport is not economical for long distance transportation of goods.
- Transportation of heavy goods or goods in bulk by road involves high cost.
- High degree of accident due to flexibility of movement

Water Transport

Advantages:

- It is a relatively economical mode of transport for bulky and heavy goods.
- It is a safe mode of transport with respect to occurrence of accidents.
- The cost of maintaining and constructing routes is very low most of them are naturally made.
- It promotes international trade. It needs minimum energy to haul unit load through unit distance.

Disadvantages:

- The depth and navigability of rivers and canals vary and thus, affect operations of different transport vessels.
- It is a slow moving mode of transport and therefore not suitable for transport of perishable goods.
- It is adversely affected by weather conditions.
- Sea transport requires large investment on ships and their maintenance.

Air Transport:

Advantages:

- It is the fastest mode of transport.
- It is very useful in transporting goods and passengers to the area, which are not accessible by any other means.
- It is the most convenient uneconomical mode of transport during natural calamities.
- It provides vital support to the national security and defence

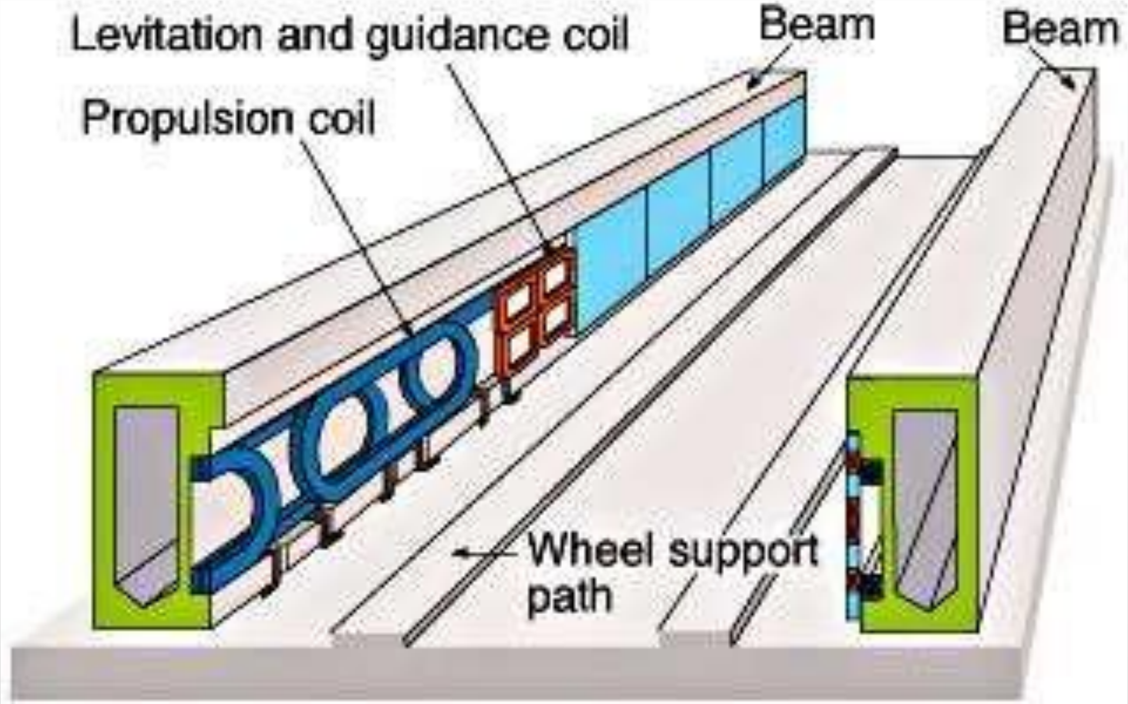
Disadvantages:

- It is relatively more expensive mode of transport.
- It is not suitable for transporting heavy and bulky goods.
- It is affected by adverse weather conditions.
- It is not suitable for short distance travel.
- In case of accidents, it results in heavy losses of goods, property and life.

Modern trends in railways

- MAGLEV
- TUBE
- METRO

- MAGLEV Trains: The technology of such trains is based on principle of magnetic repulsion.
- MAGLEV trains runs on U-shaped guide way. The train as well as the guide way will be equipped with magnets having south and north pole arranged alternately.



Tube railways :- The railway provided underground at a greater depth of about 18 m or more (up to 52 m) are called tube railways.

This system of railways is so called as the section of the underground tunnels, carrying the track, is to avoid the interference of the tracks with *water* and *gas pipes, sewerage systems* and *oil* or *drainage pipes,* etc

Some important features of the tube railways are given below :-

- The railways stations have to be of cylindrical form.

- Escalators or moving stair cases are to be constructed to reach the tube railways.
- Only electric traction to be used to avoid the smoke and ventilation problems.
- Automatic signaling system is to be used.

Such a mechanism of the train is to be used that it cannot start until all the doors are closed, and it automatically stops, if the signal is at ‘STOP’ position.

This system of railways is used by the *London Post Office* in transporting mails through a small diameter tunnel with automatic control without any driver.

A **Metro or rapid transit** system is a public transport system in an urban area with high capacity, high frequency not needing timetables, is fast and is segregated from other traffic. Operating on an exclusive right of way, rapid transit systems are typically grade separated and located either in underground tunnels (subways) or elevated above street level (elevated transit line).

Important Technical Terms

There are many important technical terms concerning to Railways, but a few terms which are of immediate concern are only discussed bellow:-

1. Railway track:-A track formed of rails of iron or steel along which trains are driven is known as railway track.

   In general, the term railway also includes all lines of rails, sidings or branches.

2. Rolling stock:- The locomotives, passenger coaches and goods wagons which roll or run on railway tracks constitute rolling stock.

3. Locomotive:- The mechanical device which transfers chemical energy of fuel into mechanical energy in the form of motion is called locomotive.

The fuel used in the locomotives may be in the form of water and coal, diesel or electricity.

4. Wagons :- The goods compartments are called wagons. This term applies only to good stock.
5. Coaches or vehicles :- The passenger compartments are called coaches or vehicles. This term applies only to coaching stock.

6. Siding: when a branch starting from main line terminates at the dead end with a buffer stop is known as siding.
7. Ballast: is the granular material packed under and around the sleepers to transfer the loads from the sleepers to subgrade.

TYPES OF GAUGES PREVALENT IN INDIA

The different gauges prevalent in ***India*** are of the following these types :-

1. ***Broad gauge (1676),***
2. ***Meter gauge (1000),***
3. ***Narrow gauge (762 mm & 610 mm).***

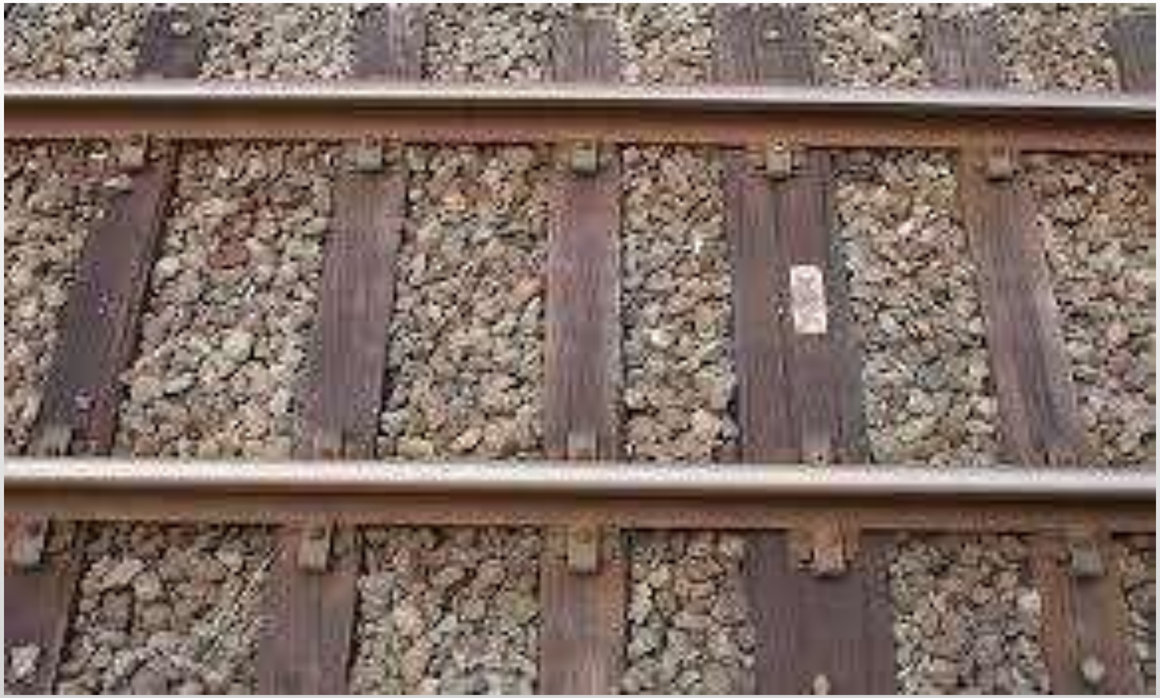
In India, efforts are being made to convert all N.G. and M.G. lines to B.G. lines on important sections as and when funds are available.

Elements of permanent way

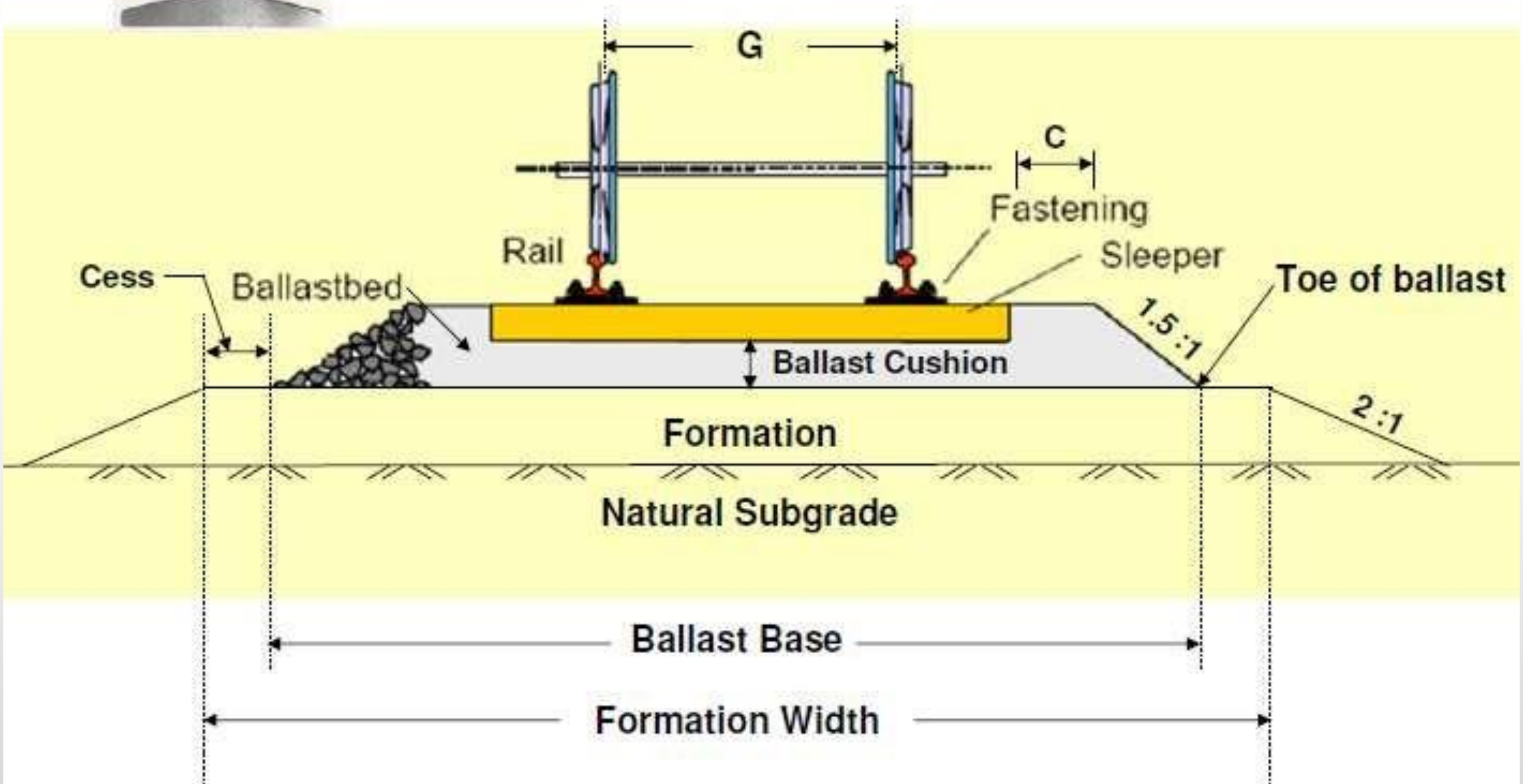
- ✓ Sub-grade
- ✓ Ballast
- ✓ Sleepers
- ✓ Rails
- ✓ Fixture and Fastening

Permanent Way

Permanent way: The combination of ***rails,*** fitted on ***sleepers*** with the help of ***fixtures*** and ***fastenings*** and resting on ***ballast*** and ***subgrade*** is called the railway track or permanent way.



Track Structure



Track Cross-section

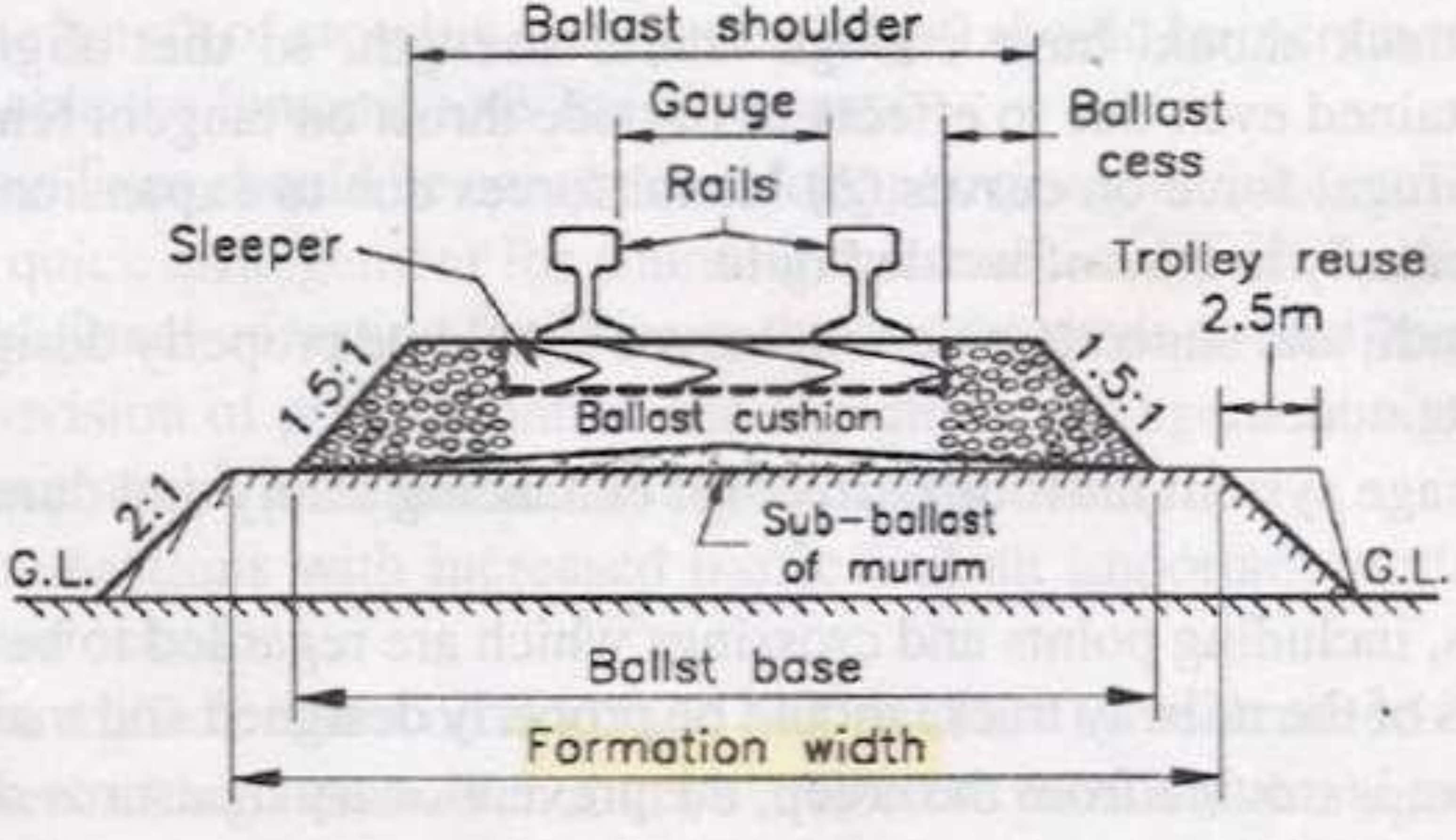


Fig. 3.1 Typical Cross-section of a Permanent Way on Embankment.

Track Cross-section

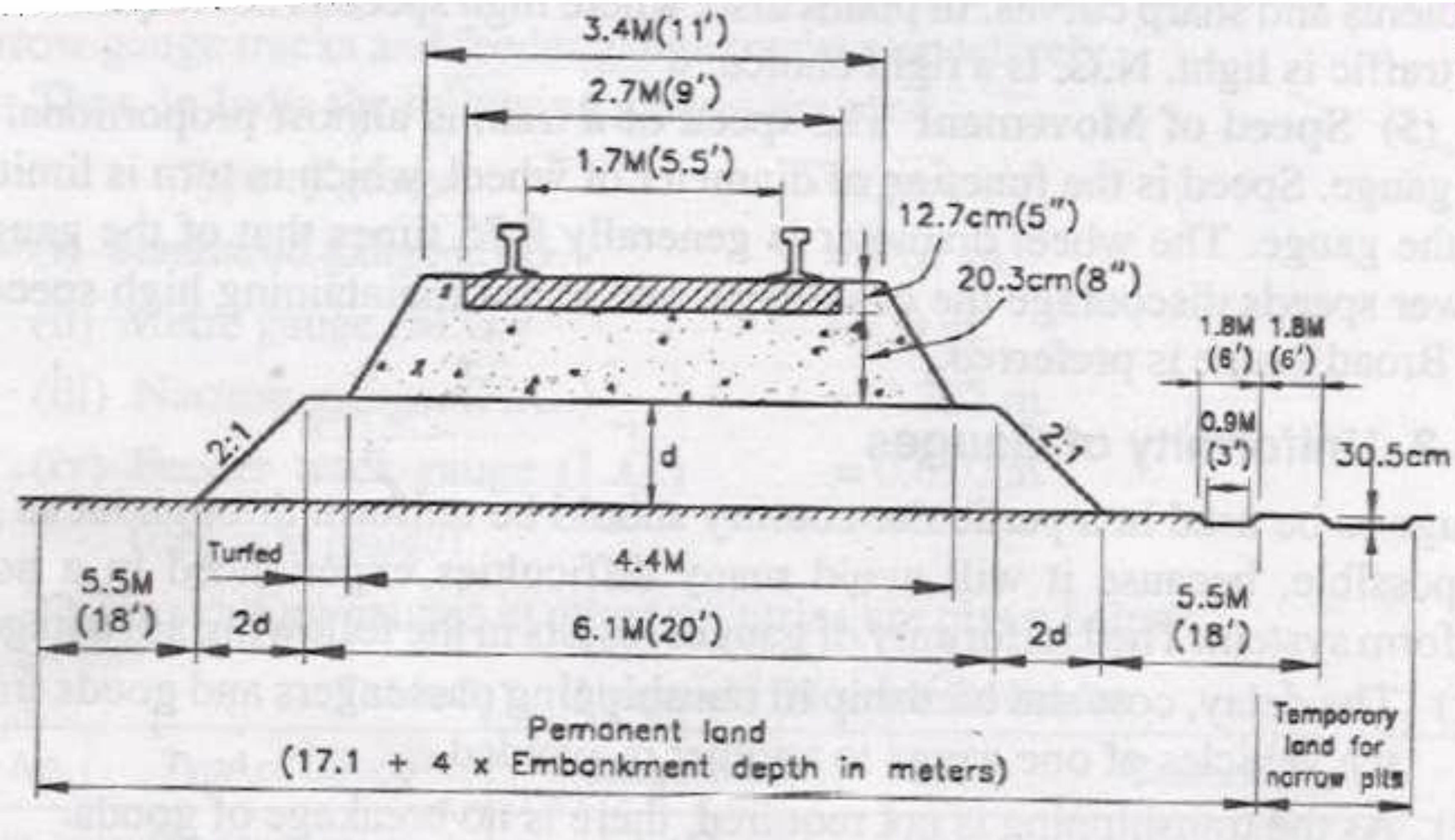
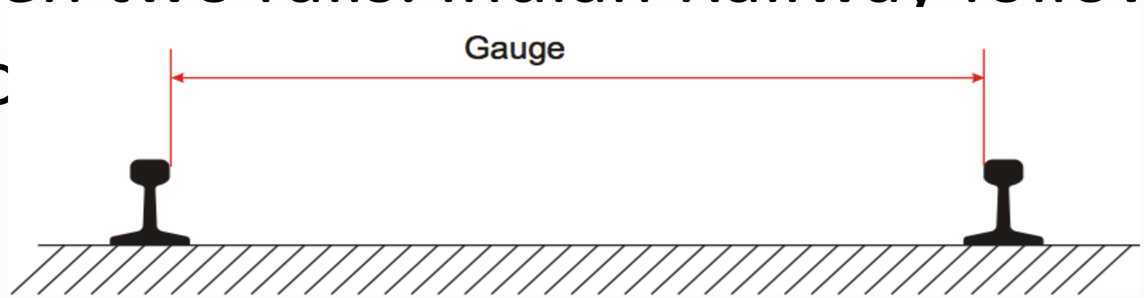


Fig. 3.2 The Cross-section of a B.G. Track in Embankment (on Straight Track)

Track Components

- Gauge: defined as the minimum distance between two rails. Indian Railway follows this practic



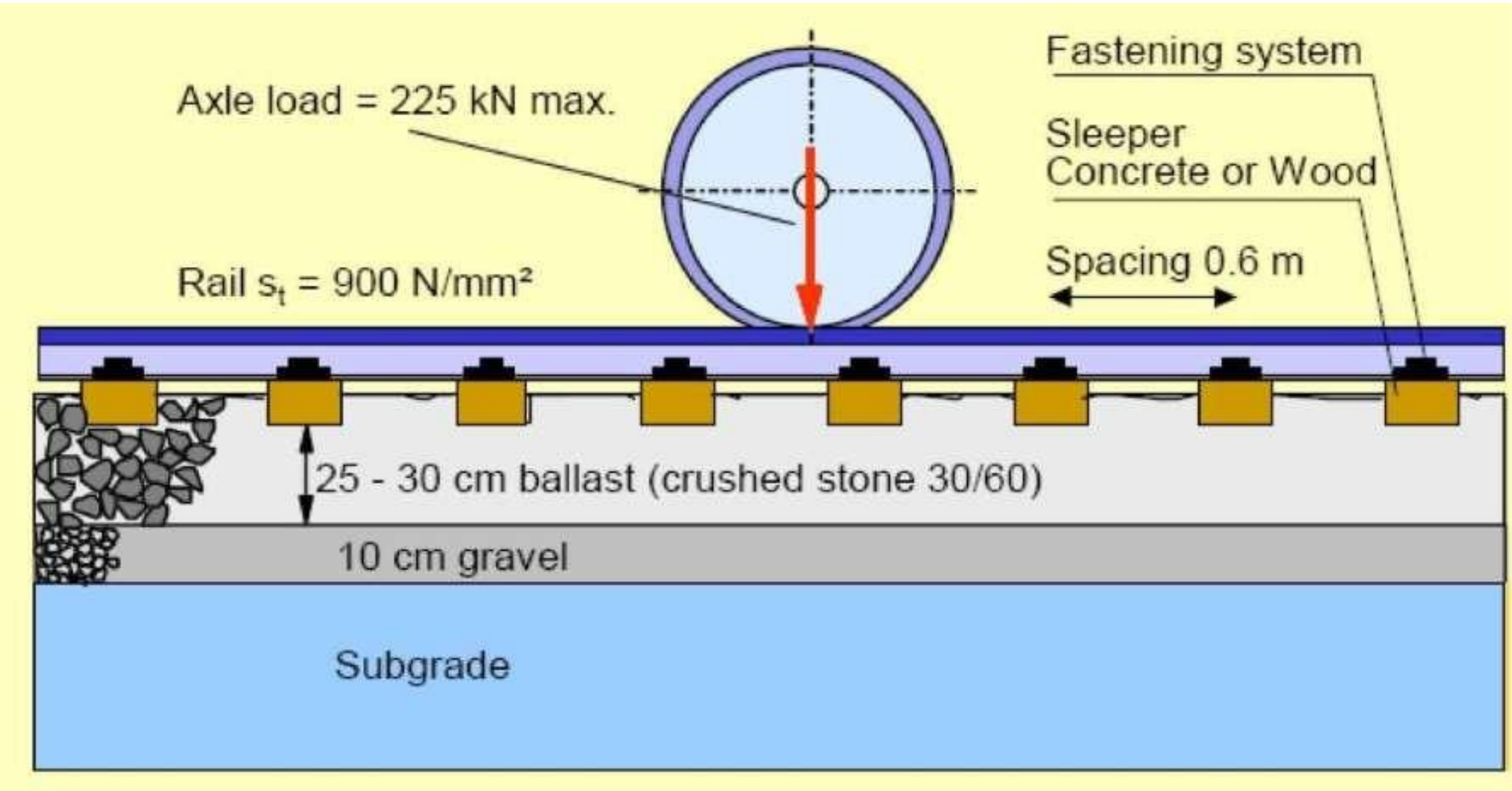
- Rails act as girders to transmit the wheel load to the sleepers.
- Rails are joined in series by welding a few of them (5 of them) and the welded lengths are joined by fish plates and bolts.

- Rails are fixed to sleepers by different types of fixtures and fastenings (chairs, bearing plates, fish plates, fish bolts, spikes etc.).
- Sleepers hold the rails in proper position with respect to their proper tilt, gauge and level and transmit the load from rails to the ballast. These sleepers are suitably spaced, packed and boxed (the process of filling the ballast around the sleepers) with ballast. The typical length of a BG sleeper is 2.7 m.
- Ballast is a high quality crushed stone with desired specifications placed directly below the sleeper.

- Ballast distributes the load over the formation and holds the sleepers in position and also functions as drainage layer.
- Formation is the compacted and prepared subgrade which is the part of embankment or cutting
- Natural subgrade is the soil in the natural ground on which the track rests.
- Ballast cushion: The depth of ballast below the bottom of the sleeper, normally measured under rail seat is termed as ballast cushion.

- **Ballast shoulder:** Ballast provided beyond the sleeper edge is termed as ballast shoulder (shown as *C* in Fig., typically 0.35 m in a BG track)
- **Ballast Base:** It is the bottom width of ballast-bed (typically 4.4 m in a BG track).
- **Formation width:** It is the top width of embankment or bottom width of cutting (Typically 6.1 m in a BG track)
- **Cess width:** Width of formation beyond the toe of ballast is termed as cess width.

Conventional track structure



REQUIREMENTS OF AN IDEAL PERMANENT WAY

The following are the principal requirements of an ideal permanent way or of a good railway track :-

i. The gauge of the permanent way should be correct and uniform.
ii. The rail should be in proper level in straight portion. Proper amount of *super elevation* should be provided to the outer rail above the inner rail on curved portion of the track.
iii. The permanent way should be sufficiently strong against lateral forces.

iv. The curves, provided in the track, should be properly designed.
v. An even and uniform gradient should be provided through out the length of the track.
vi. The *tractive resistance* of the track should be minimum.
vii. The design of the permanent way should be such that the load of the train is uniformly distributed on both the rails so as to prevent unequal settlement of the track.
viii. All the components parts such as rails, sleepers, ballast, fixtures and fastenings, etc. should satisfy the design requirements.

ix. All the points and crossings, laid in the permanent way, should be properly designed and carefully constructed.
x. It should be provided with proper drainage facilities so as to drain off the rain water quickly away from the track.
xi. It should be provided with safe and strong bridges coming in the alignment of the track.
xii. It should be so constructed that repairs and renewals of any of its portion can be carried out without any difficulty.

Length of Indian Railway Track

- ***Route kilometer***: this is the route length of railway between origins and destinations
- ***Running track kilometer**:* This is the length of running track on a route. On a route with double track, the running track kilometer is about twice the *route kilometer.*
- ***Total track kilometer*** is the physical length of track available. This length is arrived at after giving due weightage for the length of track on track junctions, sidings, etc., and adding it to the *running track kilometer.*

Length of Indian Railway Track

Type of Track	Length*, km
Broad Gauge (BG)	46806
Meter Gauge (MG)	13290
Narrow Gauge (NG)	3124
Total track *route km*	63220
Total *running track km*	83859
Total *track km*	108486

*As on 31st march 2004

Selection of Guages

1.Cost of construction

- There is marginal increase in the cost of earthwork, rails, sleepers, ballast, and other track items with gauge.
- The cost of station buildings, platforms, signals, bridges, tunnels and culverts etc., is same more or less for all gauges.
- There is little proportional in the acquisition of land.
- The cost of rolling stock is independent of the guage used for same volume of traffic.

2.Volume and nature of traffic.

- For heavier loads and high speed, the wider guage are required because subsequently the operating cost per tonne-km is less for higher carrying capacity.

3.Speed of movement

- Speed is a function of dia. of wheel, which in turn limited by the guage. (wheel diameter = 0.75 x Gauge).

4.Development of areas

- Narrow guages can be used for thinly populated area by joining under developed area with developed or urbanised area.

5.Physical features of the country

- Use of narrow guage is warranted in hilly regions where broad and meter guage are not possible due steep gradients and sharp curves.

Rails

The rails on the track can be considered as steel girders for the purpose carrying axle loads. Flat footed rails are mostly used in Indian railways.

Functions of Rails

- Provide hard, smooth and unchanging surface for the passage of heavy moving loads with minimum friction steel rails and steel wheels.
- The rail material should be such that it gives minimum wear to avoid replacement and failure.

- Rail transmit loads to the sleepers and consequently reduce pressure on ballast and formation below.

Composition of rail steel

For ordinary rails

Carbon (C) - 0.55 to 0.68 percent

Manganese (Mn) - 0.65 to 0.9 percent

Silicon (Si) - 0.05 to 0.3 percent

Sulphur (S) – 0.05 percent or below

Phosphorus (P) – 0.06 percent or below

For rails at points and crossings

Carbon (C) - 0.5 to 0.6 percent

Manganese (Mn) - 0.95 to 1.25 percent

Silicon (Si) - 0.05 to 0.2 percent

Sulphur (S) – 0.06 percent or below

Phosphorus (P) – 0.06 percent or below

Requirements of rails

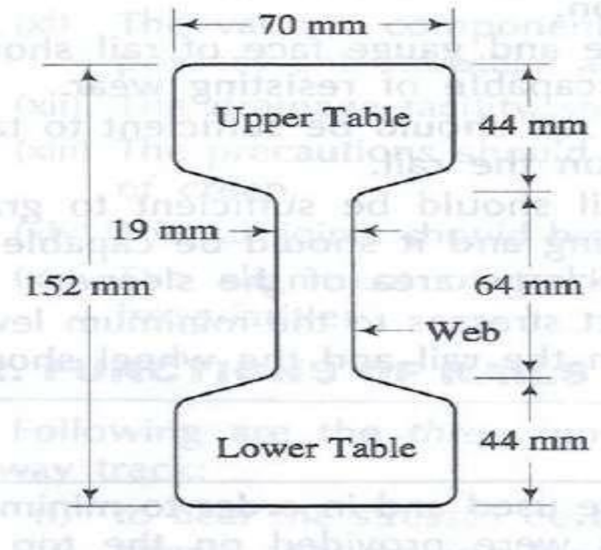
- They should be of proper composition of steel and should be manufactured by open hearth or duplex process.
- The vertical stiffness should be high enough to transmit the load to several sleepers underneath.
- Rails should be capable of withstanding lateral forces. Large width of head and foot endows the rail with high lateral stiffness.
- The head should be sufficiently deep to allow for an adequate margin of vertical wear.
- Web of the rail should be sufficiently thick to bear the load coming on it and should provide adequate flexural rigidity in horizontal plane.

- Foot should be wide enough so that rails are stable so that rails are stable against overturning especially on curves.
- Bottom of the head of rail and top of the foot should be so shaped as to enable the fish plate to transmit the vertical load efficiently from head to the foot at rail joints.
- The centre of gravity of the rail section must lie approximately at mid height so that the maximum tensile and compressive stresses are equal.
- The tensile strength of the rail piece should not be less than 72 kg/mm^2.

Types of rail sections

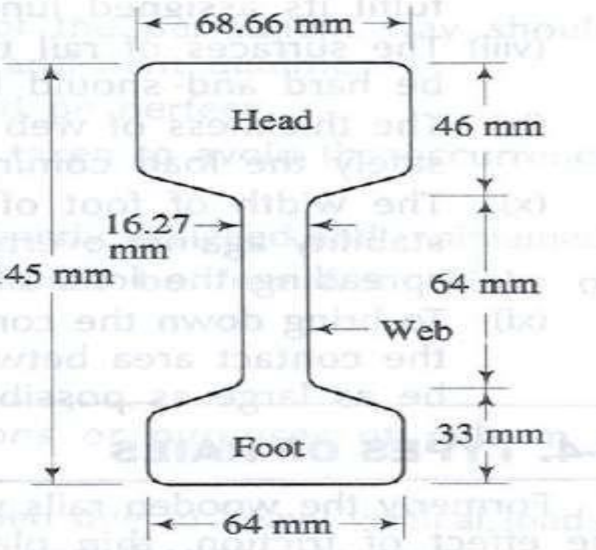
- Double headed rails(D.H Rails)
- Bull headed rails(B.H rails)
- Flat footed rails(F.F rails)

In the beginning, the rails used were double headed(D.H) of a dumb-bell section. The idea behind using of these rails was that when the head was worn out in course of time, the rail can be inverted or reused. But the experience shows that such indentation are formed in lower table due to which smooth running over that surface at the top was impossible.



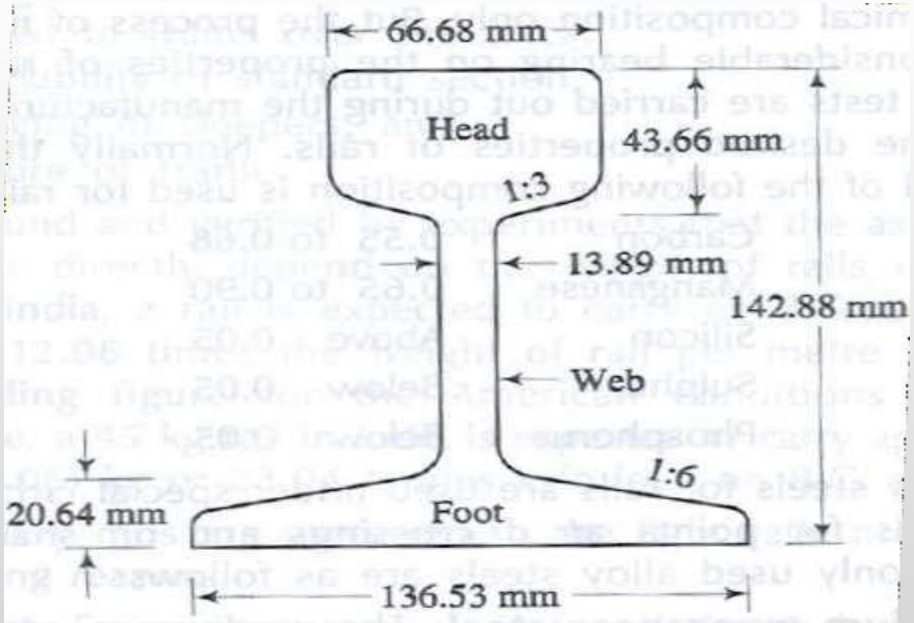
Double headed rail

FIG. 5-1



Bull headed rail

FIG. 5-2



Flat footed rail

The next evolution was that of a bull headed rail in which the head is made little thicker and stronger than the lower part, by adding more metal to it, so that even after wear, it can withstand stresses.

In designing flat footed rails it was initially thought that flat footed rail can be fixed to the sleepers directly and would eliminate the need for chairs and keys required for the bull headed rails. However it was observed that heavy train load cause the foot of the foot of rail to sink into wooden sleeper, to remedy this steel plates are used between the sleeper and the rails at joint and other important places.

Table 6.3 Comparison of Rail Types

S. No.	Point of Comparison	*Flat-footed Rails*	*Bull-headed Rails and Double-headed Rails*
1.	Strength and Stiffness	These have more strength and stiffness for the same weight, both laterally and vertically.	These have less strength and stiffness.
2.	Laying and Relaying	Fitting of these rails is simpler and so can be easily laid and relaid. No chairs are required.	The fitting of these rails is difficult and time-consuming as they are supported on chairs.
3.	Arrangements at points, crossings and at sharp curves	The arrangements are simpler and easy.	The arrangements are complicated and difficult.
4.	Alignment and stability of track	In this, impact of Rolling wheels affects the fittings and the loosening of fittings disturbs the alignment and gives less stability	These rails when fitted on chairs, provide a more solid, smooth track and better stable alignment.
5.	Initial cost	These rails require lesser and cheaper fastenings, so the initial cost is less.	These require more and costly fastenings and hence initial cost is more.
6.	Rigidity	These rails can be used, without bearing plates on sleepers as these rails are strong to withstand vertical loads. Hence they are more rigid.	These rails without chairs cannot be used on inferior type of sleepers, being less strong against vertical loads. Hence they are less rigid.
7.	Inspection	Daily inspection is not necessary as no special risk is involved.	In case of B.H. or D.H. rails, daily inspection of wooden keys is necessary.
8.	Replacement of rails	In F.F. rails, the dog spikes have to be taken out in addition to fish bolts and fish plates to change the rail. So replacement is difficult.	These rails can be changed easily by driving out the keys and taking out fish bolts and fish plates, without disturbing sleepers.
9.	Maintenance cost	The maintenance cost is less.	It requires heavy maintenance cost.
10.	Suitability	These are more suitable due to better stability, economy, strength and stiffness.	These are more suitable when lateral loads are more important rather than vertical loads.

Standard rail sections & Rail length

Table 6.1. Standard Rail Sections Gauge-wise

Gauge	*Rail Section*	*Type of Section*	*Rail Length*	*Rail Section kg/m*	
1. Broad Gauge (B.G.)	60 kg/m 52 kg/m 90 lbs/yd	60 MR (UJC) 52 MR (IRS) 90 R (RBS)	13 metre (42 ft old)	60.34 51.89 44.61	60 MR 52 MR 45 MR
2. Metre Gauge (M.G.)	90 lbs/yd 75 lbs/yd 60 lbs/yd	90 R (RBS) 75 R (RBS) 60 R (RBS)	12 metre (39 ft old)	44.61 37.13 29.76	45 MR 37 MR 30 MR
3. Narrow Gauge (N.G.)	50 lbs/yd	50 R (RBS)	12 metre (39 ft old)	24.80	25 MR

Notes : Except for 60 MR and 52 MR all rails are designated in FPS units but their dimensions in weights are :

—MR (IRS) Metric Rail kg/m as per Indian Railway standards.

—R (RBS) British Rail lbs/yd as per revised British standards (RBS)

Details of standard rail sections

90 R rail section was considered adequate only for annual traffic of about 10 gross million Tonne (GMT) speeds upto 100 kmph and service life upto 20 to 25 yrs.

52 MR (i.e.52 kg/m) rails are suitable for use of speed of 130 kmph and traffic density of 20 to 25 GMT.

60 MR (i.e. 60 kg/m) rails are suitable for use upto a speed of 160 kmph and traffic density of about 35 GMT.

Table 6.2 Details of Standard Rail Sections in use on Indian Railways

S. No.	Type of Rail Section	Wt/Metre (kg)	Area of Section (Sq mm)	Dimensions of Rail Section (mm)					
				A	B	C	D	E	F
1.	50 R*	24.80	3168	104.8	100.0	52.4	9.9	32.9	15.1
2.	60 R*	29.76	3800	114.3	109.5	57.2	11.1	35.7	16.7
3.	75 R*	37.13	4737	128.6	122.2	61.9	13.1	39.7	18.7
4.	90 R*	44.61	5795	142.9	136.5	66.7	13.9	43.7	20.6
5.	52 kg** (IRS)	51.89	6615	156	136	67	15.5	51	29
6.	60 kg** (UIC)	60.34	7686	172	150	74.3	16.5	51	31.5

*As per Revised British standards '*R*' wt Ibs/sq yd (RBS)

**Weight as per Metric Standards

- **Hogged rails**: due to battering action of wheels over the end of rails, the rail get bent down and deflected at the ends, this hogging is due to loose packing under the joint and/or loose fish plate. Can be removed by

  Cropping, replacing, welding and dehogging.

- **Kinks in rails:** when the ends of adjoining rails move slightly out of position , “shoulders” or “kinks” are formed. Kinks formed due to loose packing at joints, defects in guage, and alignment, defects in cross level at joints, uneven wear of rail head, where kinks are formed at joints .

- **Buckling of rails**: buckling means track has gone out of its original position or alignment due to prevention of expansion of rails in hot weather on account of temperature variations. Causes are following

I. When expansion gap is not sufficient

II. The fish plate are bolted so tight that no slip is allowed.

III. Due to presence of longer welded rail on weak tracks.

Wear on rails

- Wear is one of the prominent defects of rails. Due to heavy loads concentrated stresses exceeds the elastic limit resulting in metal flow; on the gap or joints the ends are battered and at the curves the occurrence of skidding, slipping and striking of wheel flanges with rails results in wear and tear on rails.

Classification of wear

- On the basis of location

I. On sharp curves
II. On gradients
III. On approach to stations
IV. In coastal area etc.

- **On the basis position of wear**

I. On the top of rail
II. At the end of rail
III. on the sides of the head

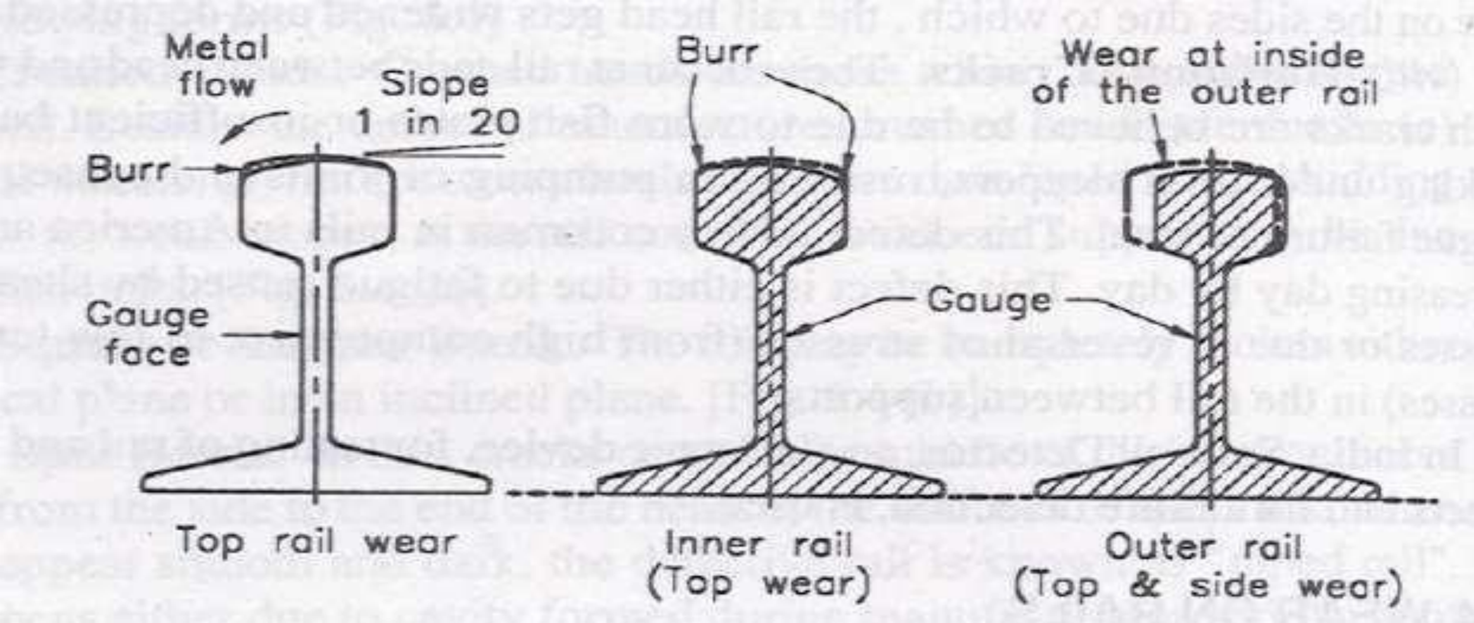


Fig. 6.5. Wear on Rails.

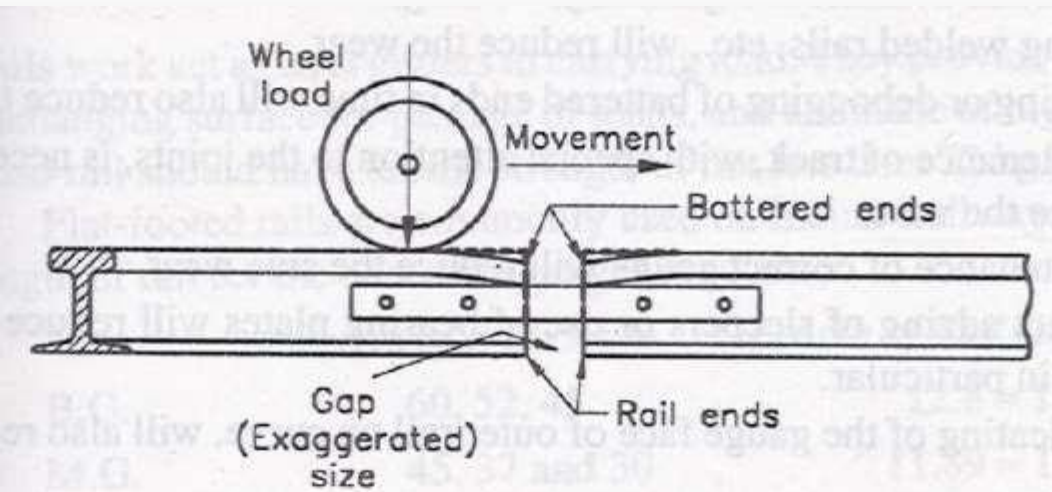


Fig. 6.6. Wear at the Ends of the Rails.

Methods to reduce wear

- When wear exceeds the permissible limit (5 % of the total weight section) the rail must be replaced.
- Use of special alloy steel at the location where wear is more.
- Reduction in number of joints by welding
- Regular tightening of fish bolts and packing of ballasts.
- Welding and dehogging of battered ends in time also the wear.

- Maintenance of correct gauge will reduce the side wear in particular.
- Lubricating of the gauge face of outer rail on curve, will also reduce the wear.
- Interchanging of inner and outer rails and changing face at curve will reduce the wear.
- Application of heavy mineral oil, in case of corrosion of rail metal under adverse atmospheric conditions, reduce the wear of rail.

Creep of rails

- Longitudinal movement of rail with respect to sleepers in a track is called creep.

Indication of creep

- Closing of expansion spaces at joints
- Marks on flanges and web of rails made by spike head, by scraping or scratching at rail slide.

Theories of creep

1. Wave action or wave theory:

Wave motion is set up by moving loads of wheels.

The vertical reverse curve ABC is formed in the rail ahead of wheels, resulting from the rail deflection under the load.

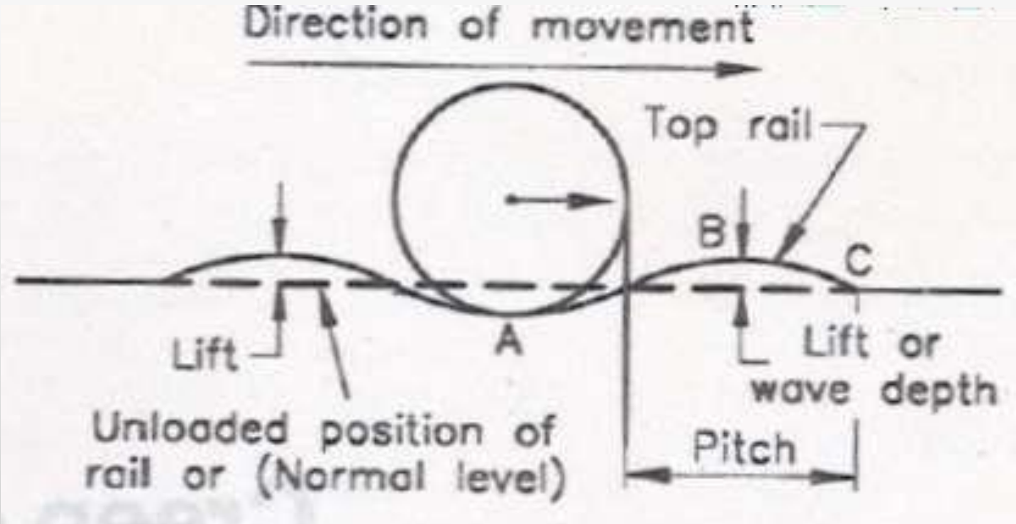


Fig. 8.2. Wave Theory of Creep (Formation of Wave)

2. Drag (or) Dragging theory:

- ✓ Backward thrust on driving wheels of locomotive of train push the rail off track backward.
- ✓ Mean while other wheel of locomotive and vehicles push the rail in the direction of travel.
- ✓ Since drag effect is more as explained in Wave Action Theory resultant creep of rails in forward direction.

3.. Percussion Theory:

This theory states that the creep is due to impact of wheels at the rail end ahead at joints. Hence as and when wheel leave the trailing rail and strike the facing rail end at each joint it pushes the rail in forward direction resulting in creep.

4. Starting, accelerating, Slowing down (or) stopping of a train:

- ✓ Backward thrust of the engine driving wheels push the rails backward when a train is starting and accelerating.
- ✓ When slowing down or stop the vehicle braking forces are push the rail forward.

5. Unbalanced Traffic:

a) Single line:

✓ Heavy equal loads pass in both direction, the creep is balanced. If not creep takes place in the heavy load direction.

b) Double line:

✓ Since loads are in unidirectional creep occurs in both directions.

Factors effecting the magnitude & direction of creep.

- Alignment of track: Creep is more on curves than on tangent tracks.
- Grade of track: More in case of steep curves, particularly while train moving downward with heavy loads.
- Type of rails: older rail have more tendency than new one.
- Direction of heaviest traffic: In heavier load moving direction occurs more creep.

Effects of creep

- Most serious effect of creep is being buckling of track.
- Common effects of creep:
- Sleepers move out of square and out of position, affects the gauge and alignment of track. As sleepers move surface is disturbed results uncomfortable riding.
- When joints are opened out beyond the permissible stress in bolts and fish plates tendency to occurrence of failure in them.
- Rails ends also battered due to occurrence of excessive gaps at joints. While at other places , joints are jammed and prevent required expansion due to thermal stresses.

Contd..

- Points and crossings get distorted, its too difficult to set them to correct gauge and alignment. Movement of switches is made difficult and interlocking is thrown out of gear.

- Its difficult to fix the removed rail at proper position during repair works since the time gap becomes too short or too long due to creep.
- Smashing of fish plates, bolts, bending of bars, kinks at joints of rails and forging of ballast ahead, common effects of creep.
- If creep is not prevented in time it will results derailment.

Remedies of creep:

1. Pulling back the rails:
   - ✓ pull back the rail to its original position. By means of crow bars and hooks provided through the fish bolts wholes of rails
   - ✓ By considering the position of joints relative to sleepers and both rails should be in respective position.
2. Provision of anchors :
   - ✓ By use of anchors and sufficient crib ballast.
   - ✓ For creep 7.5 cm-15 cm 4 anchors per rail
   - ✓ For creep 22.5 to 25 cm 6 anchors.
3. Use of steel sleepers:
   - ✓ Sleepers should be made up of good material with proper fitting. Sleepers should provide good grip with ballast to resist the movement of sleepers. Increase in no. of sleepers.

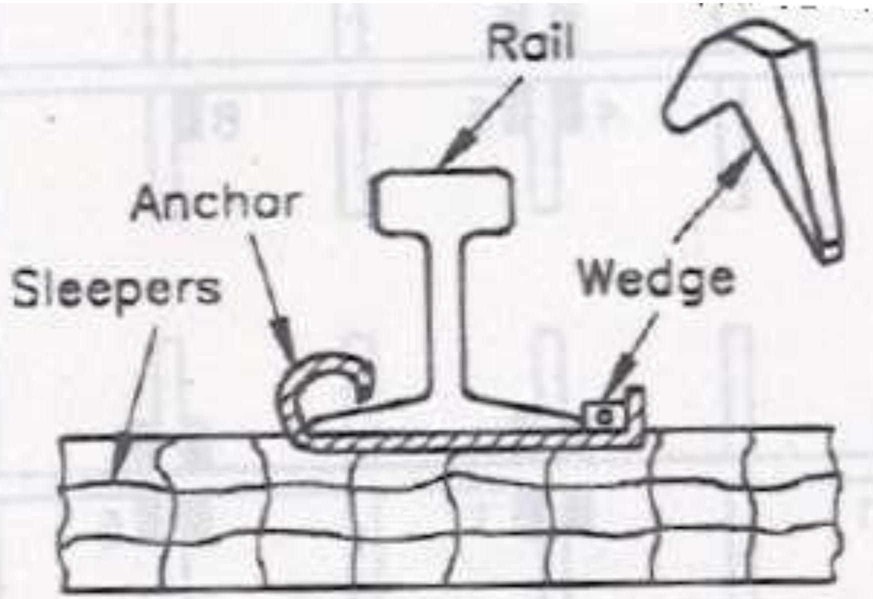


Fig. 8.5. Anchor placed by Wedging Action

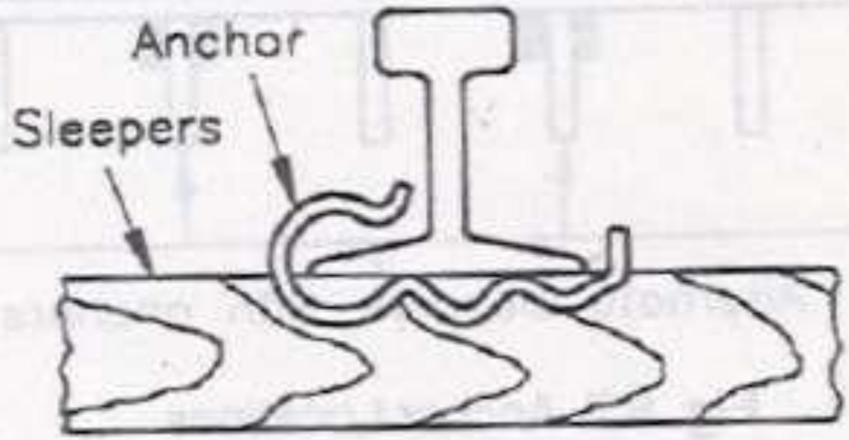
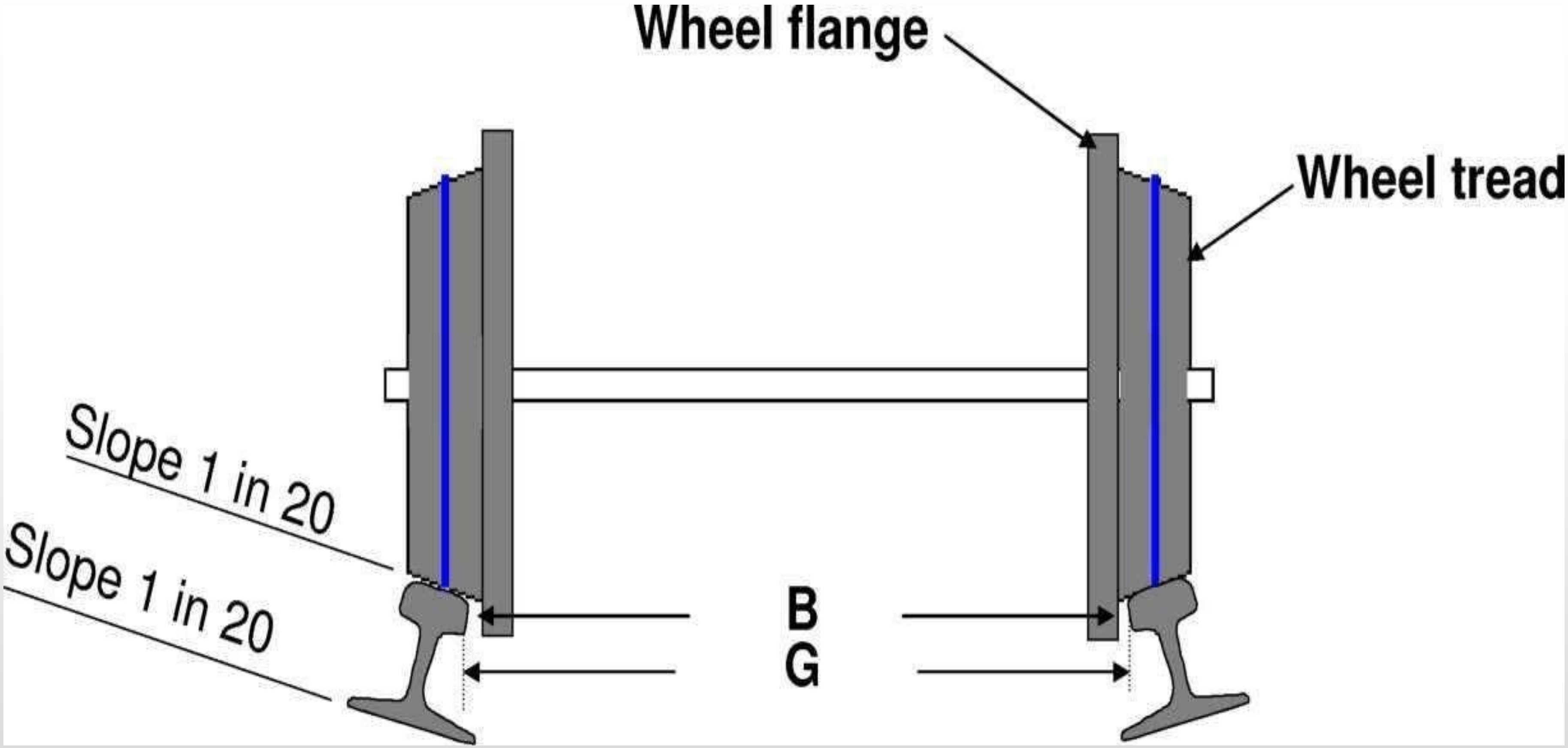


Fig. 8.6. Anchor placed by a Spring Grip

Coning of Wheels



Coning of Wheels

- The wheels of locomotive are not flat but sloped or coned at a slope of 1 in 20.
- The distance between inside edges of wheel flanges (B) is generally kept less than the gauge (G). This results in a gap of 1 cm between flange and running face of rail.

Theory of coning

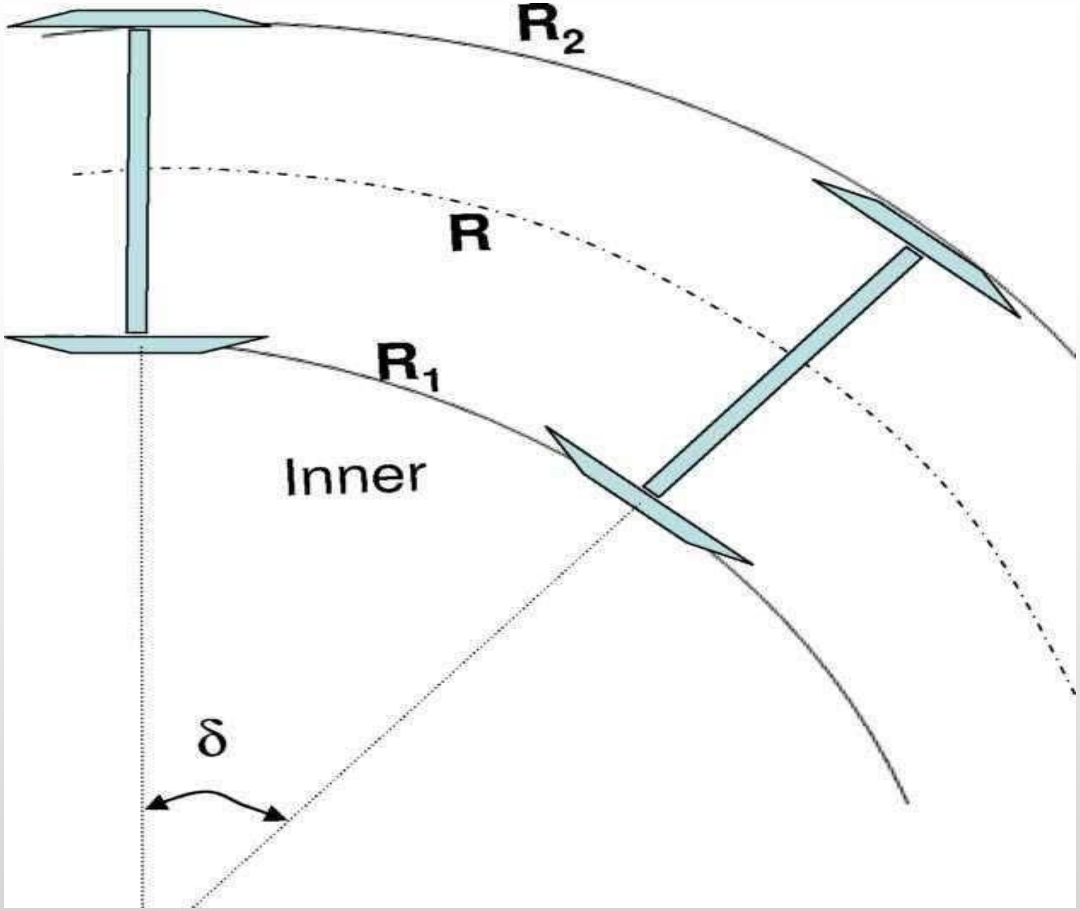
Advantages of coning:

- ✓ Reduce the wear and tear of wheel flanges and rails.
- ✓ To provide possibility of lateral movement of the axle with its wheels.
- ✓ To prevent the slipping of wheels.

Theory of coning:

- ✓ On level track, as soon as the axle moves towards one rail, the dia of the wheel tread over the rail increases, while it decreases over the other rail. This prevents the further movement and axle get back to its original position.
- ✓ Due to rigidity of the wheel base either the wheel must slip by an amount equal to the difference of length or the axle move slightly outwards to provide a tread of longer diameter over the outer rail and smaller diameter over the inner rail.

Theory of coning



If the tread dia. on both the rails is same then amount of slip is:

Slip=θ (R_2-R_1)

Where, outer radius, R_2= R+(G/2)

R_1= R- (G/2)

G=Gauge

θ= angle at centre in radians.

Slip= $\theta \times G$

G=1.676 meters for B.G

Slip= $(2\pi\theta^{\circ}/360) \times 1.676$

θ°=angle at centre (degree)

Therefore, Slip = 0.029 m per degree of central angle

SLEEPERS

- **Sleepers:** these are members laid transverse to the rails on which rails are supported and fixed to transfer the loads from rail to ballast and subgrade below.
- **Functions of sleepers:**

▪ To hold the rails to correct gauge.

▪ To act an elastic medium between the ballast and rail to absorb the blows and vibrations due to moving loads.

▪ To distribute load from the rail to the index area of ballast or to the girders in case of bridges.

▪ To support rails - at proper level in straight tracks
- at proper super elevation on curves

- Sleepers also provide longitudinal and lateral stability of the permanent track on the whole.

Requirements of sleepers: an ideal sleeper should possess the following characteristics.

- Sleeper should be economical i.e, minimum initial and maintenance cost.
- Fitting of the sleepers should be easily adjustable during maintenance operations. Such as
  - ✓Lifting
  - ✓Packing,
  - ✓Removal and replacements.

- ✓ The weight of the sleeper should not be too heavy or excessively light i.e. with moderate weight they should be for ease of handling.
- ✓ Design of sleepers should be such a way that the gauge and alignment of track and levels of the rails can easily adjusted and maintained.
- ✓ The bearing area of sleepers below the rail seat and over the ballast should be enough to resist the crushing due to rail seat and crushing of ballast under sleepers.
- ✓ Design and spacing such a way to facilitate easy removal and replacement of ballast.

- Sleepers should be capable of resisting shocks and vibrations due to passage of heavy loads of high speed trains.
- Sleepers design should be such a way they are not damaged during packing process.
- Design should be strong enough so that they are not pushed out easily due to the moving trains especially in case of steel sleepers with rounded ends.
- An ideal sleeper should be anti-sabotage and anti-theft qualities.

- Classification of sleepers.

1. Wooden sleepers:

- ✓ Wooden sleepers regarded to be best as they are fulfill all the requirements of ideal sleeper.
- ✓ Life of timber sleepers depends on their ability to resist wear, decay, attack by vermin, and quality of timber.
- ✓ Easily available (Sal, teak, chir and deodar).
- ✓ Fittings to the wooden sleepers are few and simple in design.
- ✓ Resist shock and vibrations.
- ✓ But it is difficult to maintain gauge in case of wooden sleepers.
- ✓ Service life is minimum (12 to 15 years) and maintenance cost is also high as compared to other sleepers.

Composite sleeper index (C.S.I):

- It is an index to determine the suitability of timber for use as a sleeper.
- This is measure the mechanical strength of timber, derived from its composite properties of strength and hardness.

$$C.S.I = (S+10H)/20$$

min value of CSI are 783,1352 and 1455 for track, crossing and bridge sleeper respectively.

S= strength index both for green and dry timber at 12% of moisture content.

H=hardness index both for green and dry timber at 12% of moisture content.

Treatment of wooden sleepers:

- ✓ To improve the life of timber up to 30 to 50%.
- ✓ Timber has minute cells filled with juices, therefore by replacing these juices by means of preserving solutions is known as treatment.

Preserving solutions are:

i. Creosote: Creosoting is done at temp. 49˚C and 21 kg/cm^2

ii. Salt- solution: Chloride of zink ($ZnCl_2$)-process is called Burnettising.

iii. Bichloride of mercury- salt solution (Hg Cl2)-kyanizing

2. Metal sleepers:

- ✓ These are either steel or cast iron, mostly cast iron since it is less prone to corrosion.

Requirements of metal sleepers:

- ✓ They should be capable of the tensile and compression stress due to the moving loads.

Cast iron sleepers:

a. Pot or bowl sleepers
b. Plate sleepers
c. Box sleepers
d. C.S.T 9(Central standard trial)sleepers
e. Rail free duplex sleepers

Pots or bowl sleepers:

- ✓ They consists of two bowls placed inverted on the ballast.
- ✓ Effective bearing area 0.232 sq.m is provided under each rail support.
- ✓ On top of the pot, a rail seat or chair is provided to hold the F.F rail or B.H rail with cant of 1 in 20.
- ✓ Weight of sleeper is 114 kg. it can be used on curves, sharper than 4˚ on B.G.

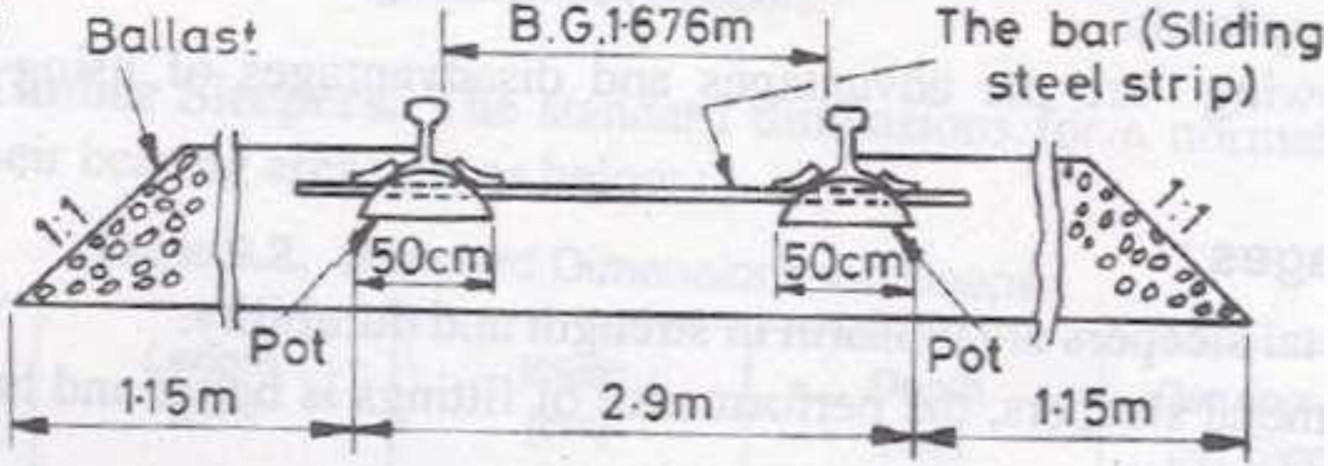


Fig. 9.4. Cross-section of Pot Sleepers.

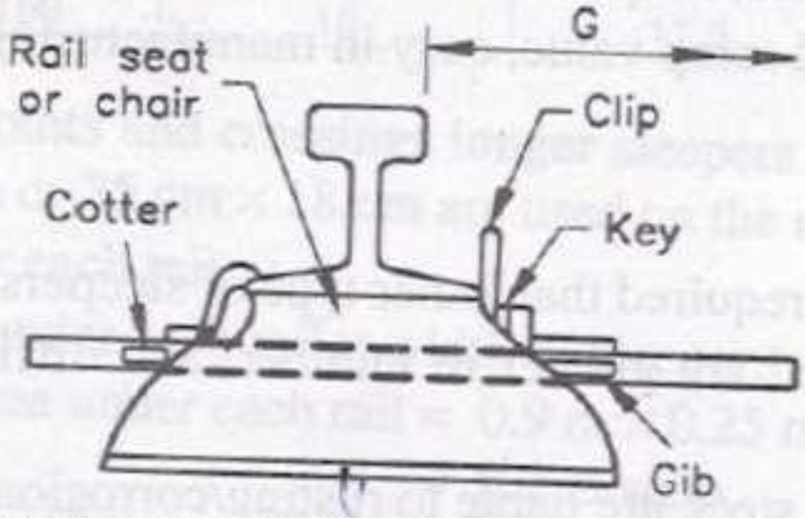


Fig. 9.5. Longitudinal View of Pot sleepers.

C.S.T-9 (Central Standard Trial-9)sleepers: it is standardized by track standard committee. It has triangular inverted pot on either side on rail seat, a plate with projecting rib and a box on the top of plate.

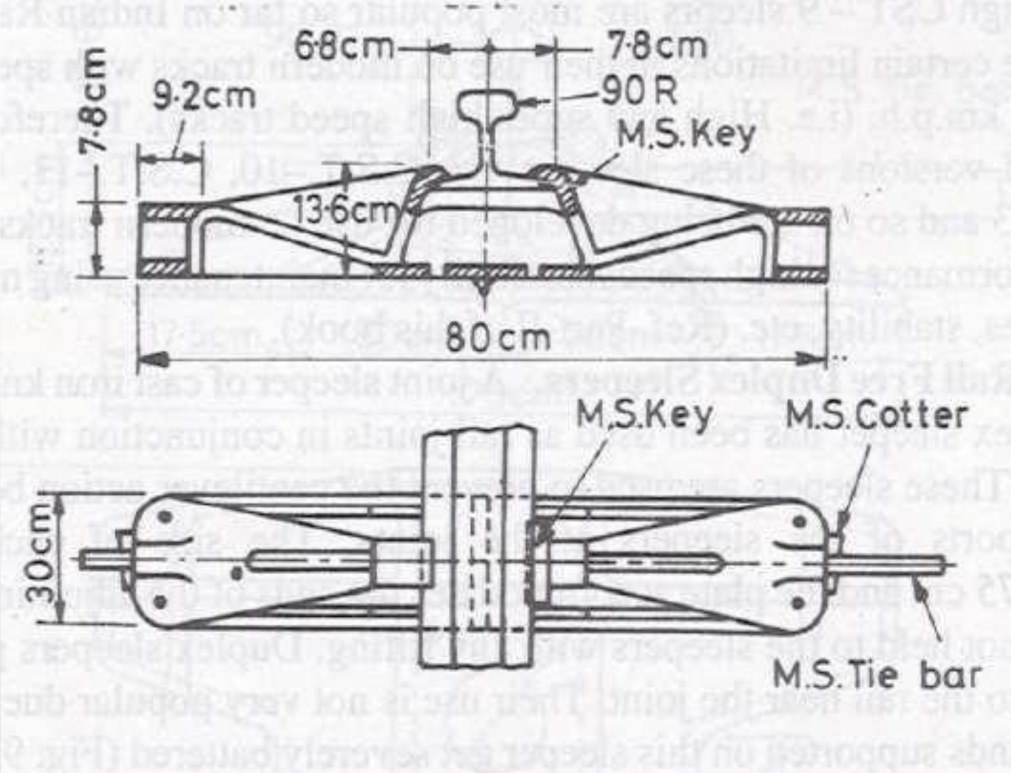


Fig. 9.6. C.S.T.–9 Sleeper.

- C.S.T.-9 sleeper for B.G. weighs 103 kgs. This can be easily assembled as shown in fig.
- Here tie bar is fastened to the plate by means of four standard cotters. Small variation in gauge can be corrected by these 4 cotters.
- Shape of cast iron support in such a way to provide stable base for the rail, lateral and longitudinal stability of track.
- Mild steel two way key is provided to resist creeping movement of the rail.
- Rail seat has 1 in 20 cant and 11.4 cm width in B.G.
- Form rigid track subjected to vibration under moving load without any damping or absorption.
- Suitable for speed up to about 110 kmph.

Steel sleepers:

Various types of steel sleepers

1. Key type a) lugs or jaw pressed out of metal

   b) with loose lugs or jaws

2. Clip bolt type
3. Saddle or spring type.

Features

- Fastening to the sleepers are less in numbers and simple in nature.
- Gauge by use of steel sleepers can be easily adjusted and maintained.
- Life of sleepers is much more than wooden sleepers.
- Cost is relatively more than wooden sleepers.

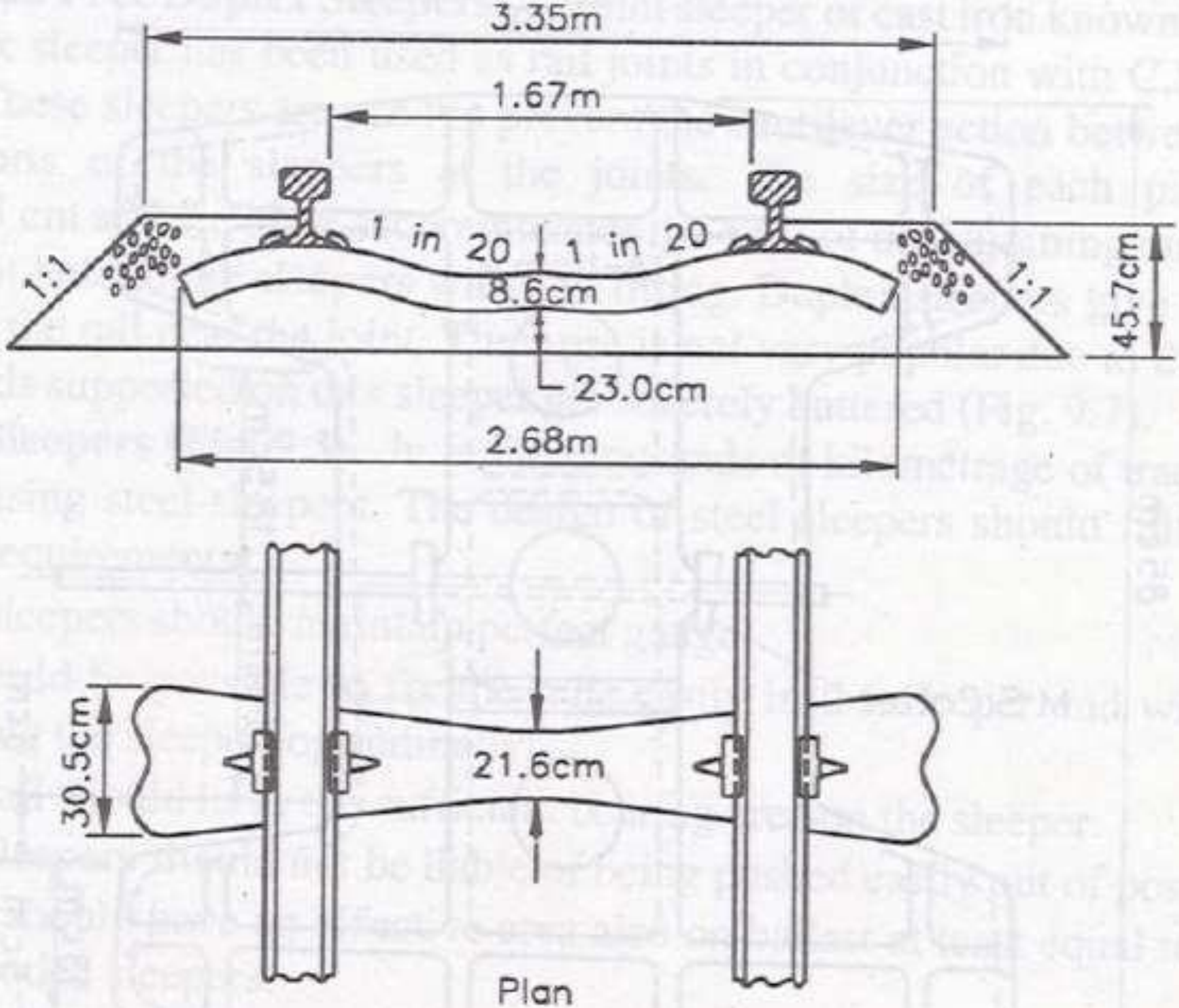


Fig. 9.8. Steel Sleepers.

3. Concrete sleepers:

Two types of concrete sleepers

i. Reinforced concrete sleepers

ii. Pre-stressed concrete sleepers.

Concrete material is called as ideal sleeper due to

i. They made up of strong homogeneous material.

ii. Impervious to effect of moisture.

iii. Unaffected by the chemical effect of atmospheric gases or sub soil salts.

iv. Easy to mould into required shapes to withstand the stresses developed by moving loads.

Reinforced concrete sleeper: these are 2 types

1. Through type: in this type when concrete sleepers is stressed, cracks on the tension side are inevitable. Though these cracks are very small they tend to enlarge with repetition of the impact loadings of fast trains. This is the major reason for the failure of this sleeper.
2. Composite tie type

Prestressed concrete sleepers:

drawbacks of previous one can be eliminated by this type of sleepers,.

1. In this concrete is put under very high initial compression.
2. The max permissible compressive strength of 211 kg/cm^2.
3. Max. cube crushing strength of concrete in the sleeper is 422 kg/cm^2 at 28 days.
4. Pre-stressed wires are stressed to an initial stress of 8.82 kg/cm^2.

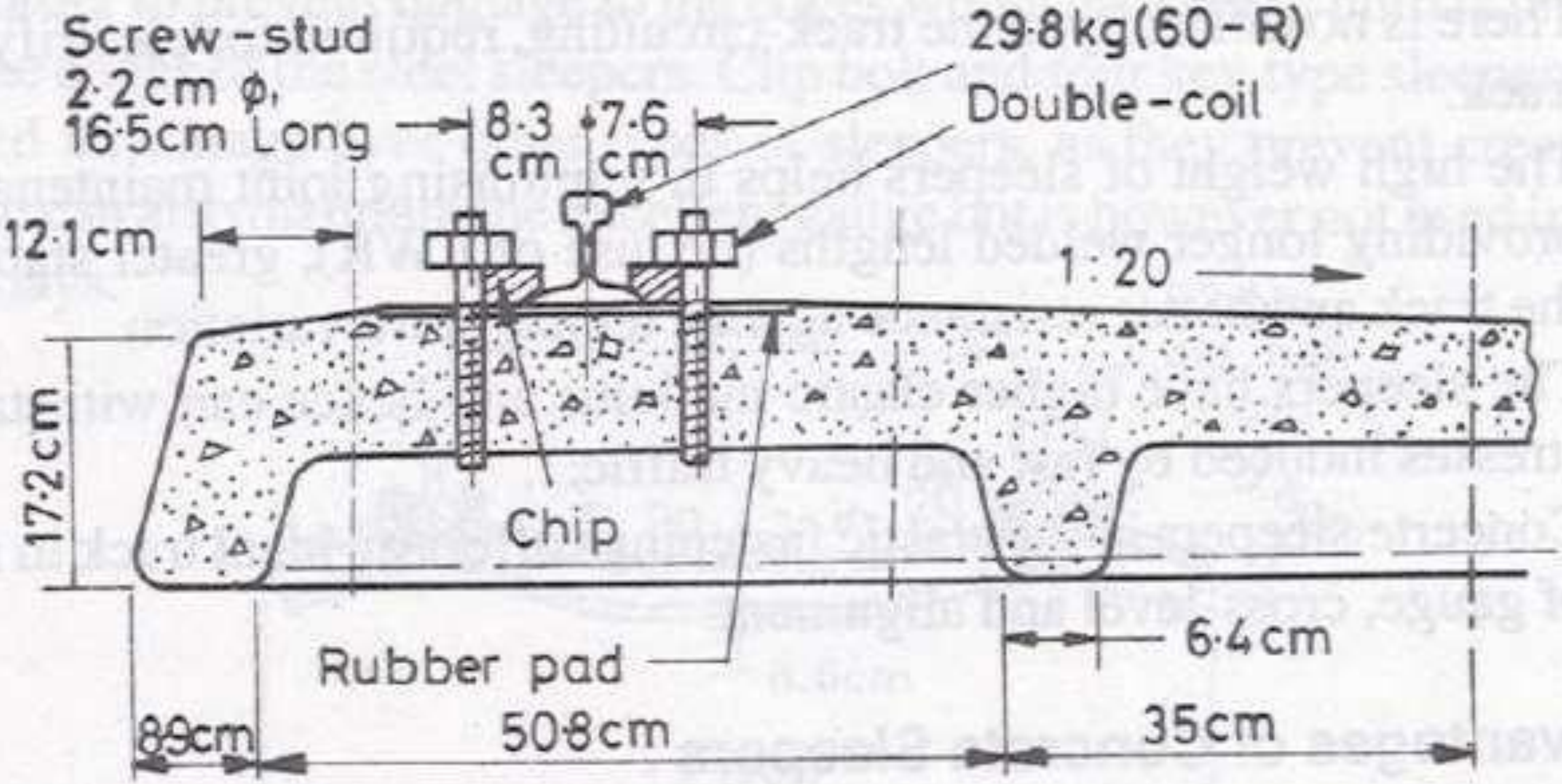
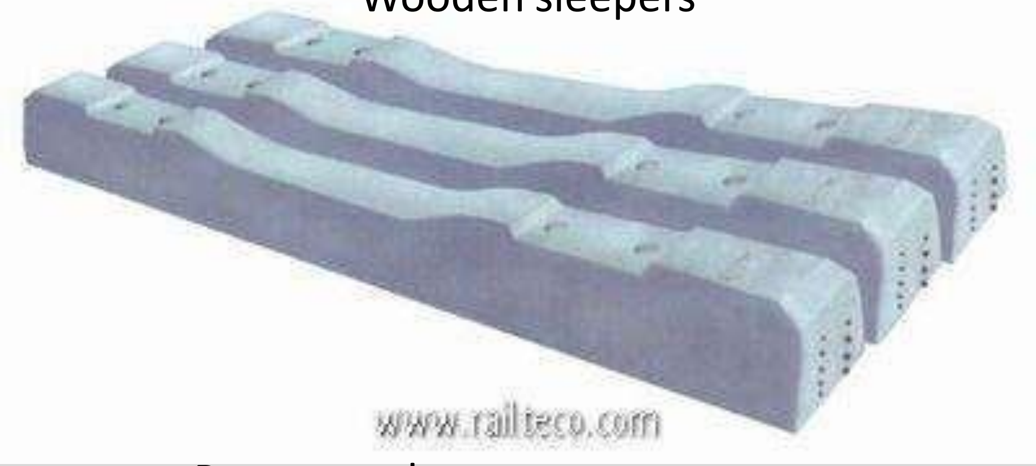


Fig. 9.13. Pre-stressed Concrete Sleeper.

Reinforced concrete sleepers

Wooden sleepers



Prestressed concrete structures

Anchors

Table 9.3. Comparison of Different Types of Sleepers

S. No. (1)	Point of Comparison (2)	Wooden Sleeper (3)	C.I. Sleeper (4)	Steel Sleeper (5)	Concrete Sleeper (6)
1.	Cost per sleeper	Low	Medium	High	Depends upon design.
2.	Life	10 to 15 years for untreated sleepers. 20 to 25 years for treated sleepers.	35 to 50 years.	35 to 50 years.	40 to 60 years.
3.	Weight per sleeper for B.G. track.	Low	Heavy	Medium	Depends upon design but heavier than others.
4.	Maintenance Cost	Higher than other sleepers.	Minimum	Moderate.	Moderate
5.	Overall economy	Cheaper in the initial cost but expensive in long run.	Costlier in first cost but cheaper in long run.	Same as for C.I.	Under trail

6.	Handling	Not liable to break under rough handling.	Liable to break under rough handling	Not liable to break, if clip and bolts are used	With improved design, not liable to break
7.	Track fittings	Requires less fittings.	Requires more fittings.	Requires less fittings.	Requires less fittings.
8.	Elasticity	Good.	Not so good	Not so good.	Not good.
9.	Laying and Relaying	Easiest.	Difficult due to large number of fittings.	Easy due to light weight.	Difficult by manual labour. Easy if mechanical devices are used.
10.	Rigidity of Track	Poor both laterally and longitudinally.	Better than timber sleepers.	Better than timber sleepers.	Best because of heavy dead weight.
11.	Suitability of Track	Generally suitable in all locations except areas of vermins and white ants. Specially suitable for points and no stings, bridges, station yards and level crossings	Suitable only for stone ballast. Unsuitable in station yards	Suitable only for stone ballast. Unsuitable for station yards and coastal areas.	Suitable for any location on railway track.

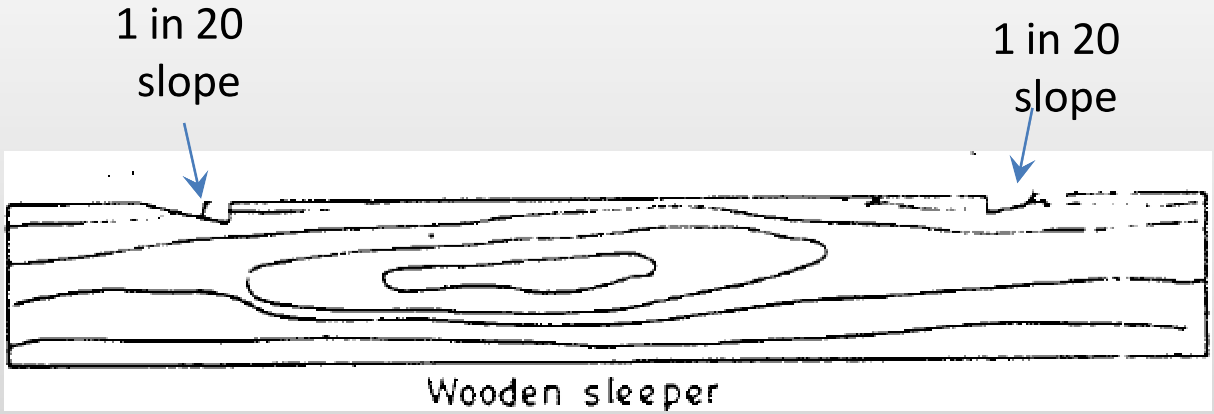
13.	Scrap value	Very little	Highest.	Next to C.I.	Nil
14.	Gauge	Does not maintain proper gauge.	Slight play in gauge due to play in the bar and socket.	Maintains proper gauge.	Depends upon design, improved design maintains proper gauge.
15.	Renewal	Easy	Difficult.	Difficult.	Difficult
16.	Gauge adjustment	Difficult.	Easy.	Easy.	Easy.
17.	Creep of rails	Heavy. Anchors are necessary in large numbers	Fittings function as creep anchors. Requires constant attention in C.S.T.–9 sleepers.	No difficulty in clip and bolt type.	No anchor is necessary.

Adzing of Sleepers:

In order to obtain an inward slope of 1 in 20 for the rail, sleepers are adzed to form a table at this slope at the rail seat.

This process is known as adzing of sleepers. Generally adzing is done for wooden sleepers.

For smooth and comfortable journey accurate adzing is required.



Ballast material:

1. Broken stone:

- ✓ It is the best material for the ballast. Mostly stone ballast is used in all important tracks.
- ✓ The best stone for ballast is a nonporous, hard and angular. Igneous rocks such as hard trap, quartzite and granite are good material and are used in large quantities for high speed tracks in India.
- ✓ For stability , graded broken stone ballast is better than ungraded one.
- ✓ The size of stone ballast should be 5 cm for wooden sleepers and 4 cm for metal sleepers.

2. Gravel or river pebbles or shingle:

Gravel is second best material for ballast material.

Source: river bed, gravel pits.

Due to smoothness of the particles these are liable to displace the sleeper and the packing does not hold.

3. Ashes or cinders:

Earlier this is available in large scale on railways since coal been used in locomotives.

It can provide excellent properties since it is very porous in nature.

It is very cheap and can be used in sidings but not in main lines as it is very soft and gets reduced due the wheel load pressure and make the track very dusty.

Due to its corrosive quality it corrodes the steel sleepers and foot of the rail.

But in emergency such as floods ashes or cinders can be used for the repairing formation or packing tracks.

4. Sand:

It is cheap and provides good drainage. It is particularly good for packing pot sleepers.

But the drawback is it gets into the moving parts and on the track causes heavy wear therefore leads to high maintenance cost.

6. Kankar:

It is a lime agglomerate. It can be used where stone is not available. It can be used in road and railways as well. Under the application of loads it will become powder therefore it can be used only in M.G & N.G.

7. Brick ballast:

Where no stone or other substitutes available it can be used. It can be easily powdered and creates dusty tracks.

8. Blast furnace slag:

It is a by-product in the manufacture of pig iron forms. The material should be hard and with high density and these are free from gas holes.

9. Selected earth

Size of ballast:

The broken stones either of too big size or too small size are found unsuitable for railway ballast.

Size of ballast depends upon

- Type of sleepers
- Maintenance method
- Location of the track.

The size of the ballast used varies from 20mm to 50mm with reasonable proportion of intermediate sizes. The exact size of the ballast depends upon the type of sleepers.

- For wooden sleepers-51mm
- For steel sleepers-38mm
- For under switches, points and crossings-25.4mm

Minimum depth of ballast section:

The wheel load dispersion in the ballast is assumed at 45˚ to the vertical.

For uniform distribution of load on the formation, ballast depth should be such that the dispersion lines should not overlap each other.

Therefore, depth of ballast can be calculated by

Sleeper spacing (s)=

width of sleeper(w)+2×depth of ballast

Tests on ballast: Ballast material quality is defined by its particle characteristics. Therefore testing of ballast material is required to define these characteristics.

Tests for ballast material:

Durability tests:

Three abrasion tests are mainly using:

Los Angeles abrasion: it's a dry test to measure toughness or tendency for breakage of aggregate.

It consists 12 steel balls in a large steel drum for 1000 revolutions. Impact of steel balls cause crushing on ballast.

Material from the test should sieve with 1.7 mm sieve.

The LAA value $=((w_1-w_2)/\ w_1)\times 100$

Here

w_1= total weight of specimen

w_2= weight of material retained on the 1.7 mm sieve.

Los Angeles Abrasion test

Crushing test:

- To test resistance of an aggregate to crushing under wheel loads.
- The aggregate passing 12.5 mm IS sieve and retained on 10 mm IS sieve is selected for standard test. Material is placed in a steel mould of 150 ×180 mm deep.
- Load is applied through the plunger at a uniform rate of 4 tonnes per minute until the total load is 40 tonnes, and then the load is released.

$$\text{Aggregate crushing value} = (w_2 / w_1) \times 100$$

Here

Total weight of dry sample taken = w_1

Weight of the material passing through 2.36mm sieve = w_2

Impact test:

It measures the toughness to sudden shocks and impact loads.

Aggregate size of passing through12.5mm sieve and retained on 10 mm sieve placed in a steel mould.

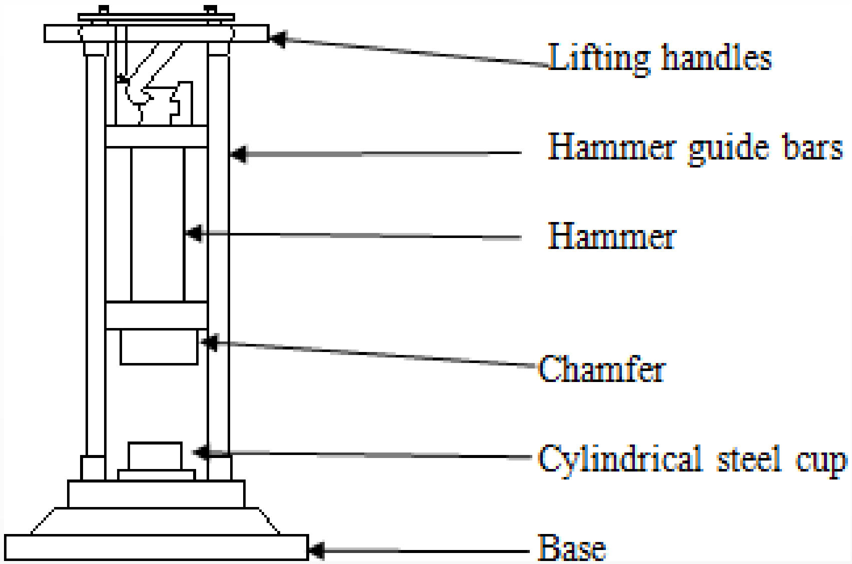
Subjected to 15 blows with 14 kg weight of hammer at a height of 380mm.

$$\text{Aggregate impact value} = (w_2/\ w_1) \times 100$$

Here

Total weight of dry sample taken = w_1

Weight of the material passing through 2.36mm sieve = w_2


Lifting handles
Hammer guide bars
Hammer
Chamfer
Cylindrical steel cup
Base

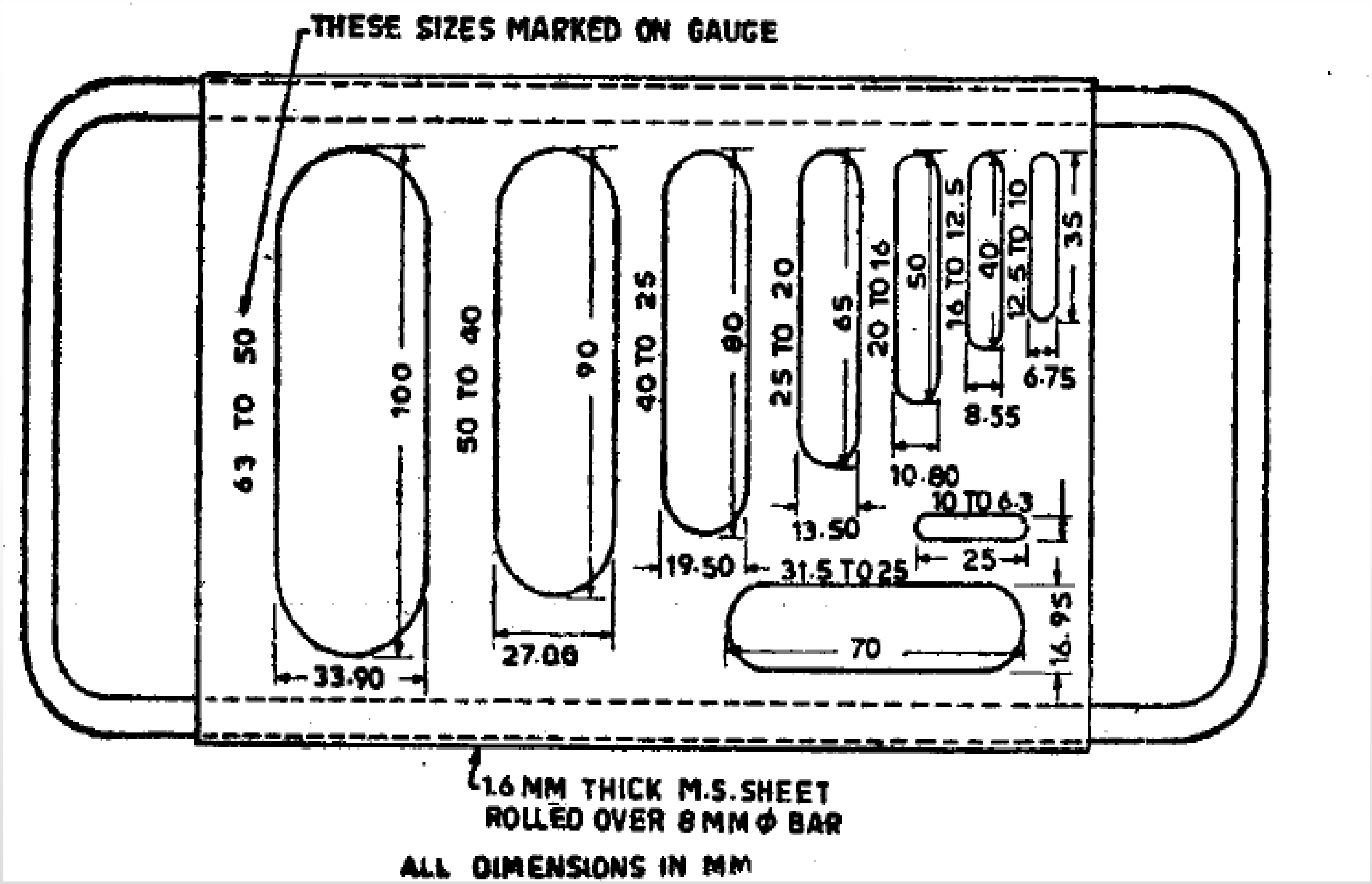

Steel mould
Tamping rod

Shape tests:

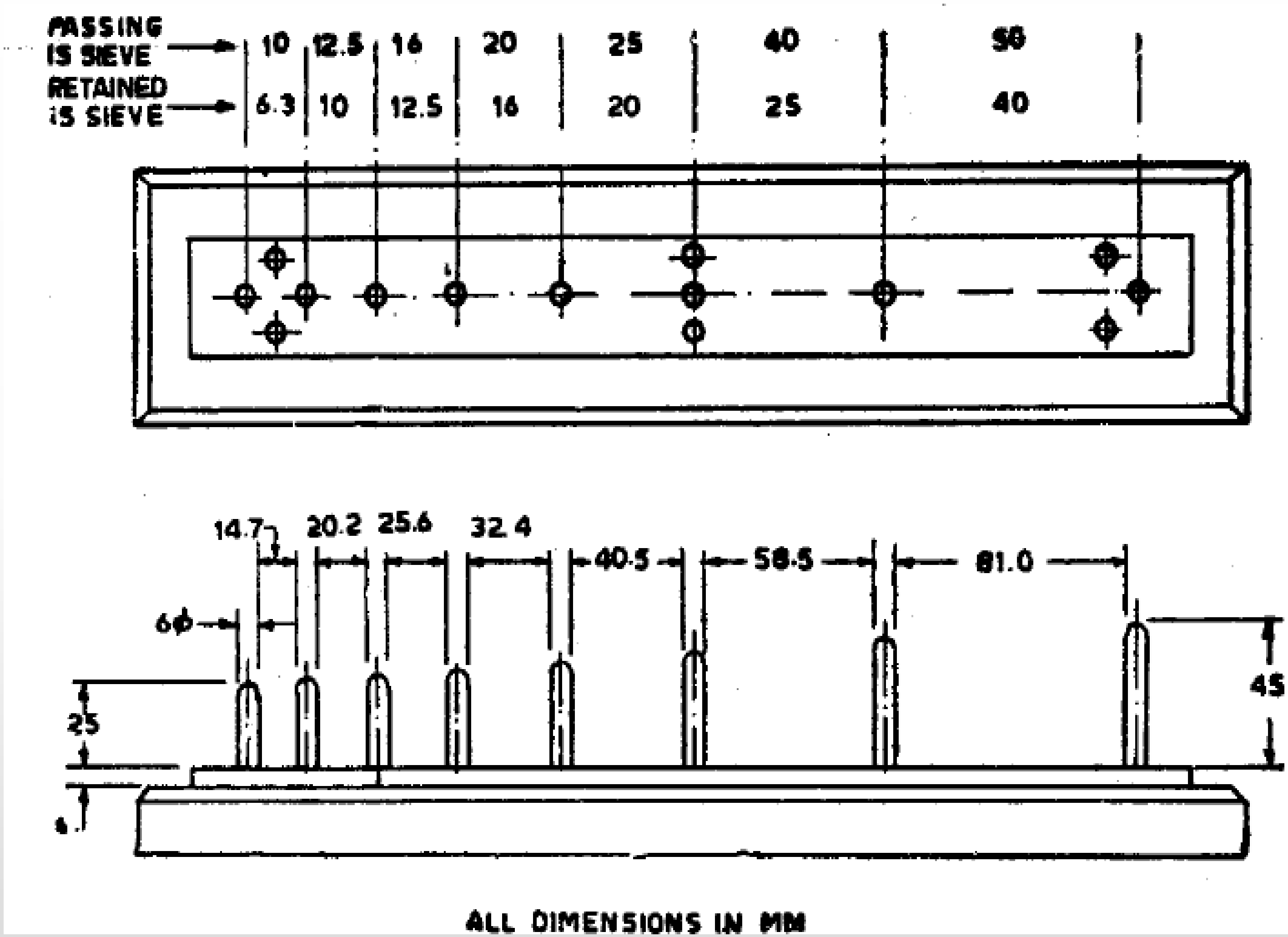
Flakiness index: The flakiness index of aggregates is the percentages by weight of particles whose least dimension(thickness) is less than 0.6 of their mean dimension.

Elongation index:

- The elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1.8 times of their mean dimension. The elongation test is not applicable to sizes smaller than6.3 mm.



THICKNESS GAUGE



Length gauge

S.no	Characteristics	Tests
1	DURABILITY	Los Angeles abrasion Mill abrasion Deval abrasion Clay lumps and friable particles Crushing value Impact
2	SHAPE AND SURFACE CHARACTERISTICS	Flatness Elongation Angularity or Roundness Fractured particles Surface texture
3	GRADATION	Size Size distribution Fine particles content
4	**UNIT WEIGHT**	**Specific Gravity** **Absorption**
5	ENVIRONMENTAL	Freeze- Thaw breakdown Sulfate soundness

Track Fittings and Fastenings

Track fittings and rail fastenings are used to keep the rails in the proper position and to set the points and crossings properly.

They link the rails endwise and fix the rails either on chairs fixed to sleepers or directly on to the sleepers.

The important fittings commonly used are:

1. Fish plates
2. Spikes
3. Bolts
4. Chairs
5. Blocks
6. Keys
7. plates

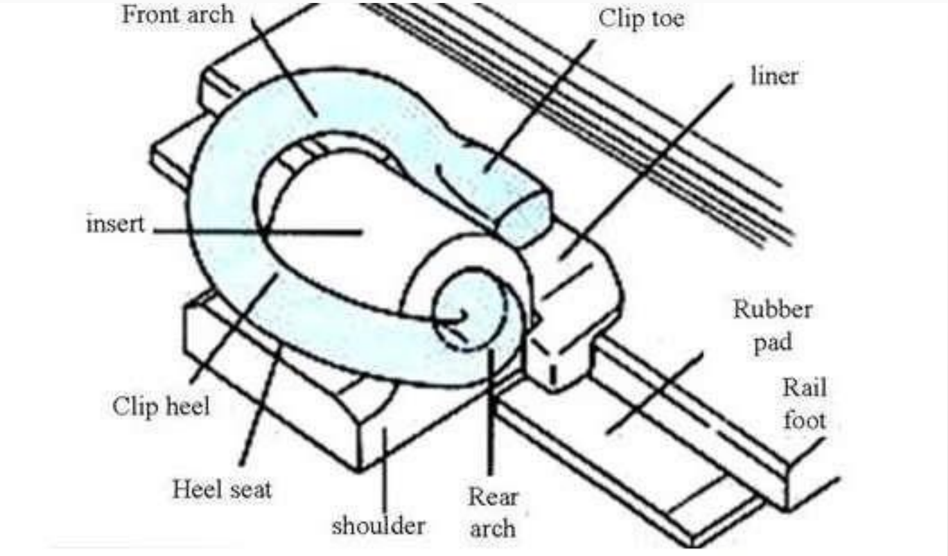


Figure 2: Schematic of rail fastening system used in the Indian Railways

Pandrol clip or elastic rail clip

- The Pandrol PR 401 clip is standard type of fastening used in I.R.
- Earlier manufactured by Messrs and Guest, Keens and Williams.
- Require very less maintenance.
- Spring steel bar with a dia of 20.6 mm and is heat treated.
- It exerts a toe load of 710 kg for a nominal deflection of 11.4 mm.
- Can be fitted to wooden, steel, cast iron and concrete sleepers.
- Disadvantage is that it can be taken out using ordinary hammer so does not provide enough safeguard.

Fish plates: these are used in rail joints to maintain the continuity of the rails and to allow expansion and contraction.

Requirements of fish plates:

- Fish plates should maintain the correct alignment both horizontally and vertically.
- They should support the underside of the rail and top of the foot.
- Provide proper space for the expansion and contraction
- They should be made up of such a section to withstand shocks and heavy stresses due to lateral and vertical B.M

Sections of fish plates:

Various sections have been designed to bear the stresses due to lateral vertical bending.

Standard section is bone shaped

Fish plates

Design of fish plate section is depends up on the various stresses due to lateral and vertical bendings.

The strength of fish plate can be increased by means of increase in the depth but the c/s of fish plate is constant through out the length.

Ex:

Bone shaped plate for F.F rails

Increased depth fish plate for B.H rail.

Spikes:

For holding the rails to the wooden sleepers, spikes of various types are used.

Requirements of spikes:

Spikes should be strong enough to hold the rail in position and it should have enough resistance against motion to retain its original position.

The spikes should be deep for better holding power.

It should be easy in fixing and removal from the sleepers.

The spikes should cheap in cost and it should capable of maintaining the gauge.

Various types of spikes:

1. Dog spikes: For holding F.F rail to wooden sleeper.

These are stout nails to hold rail flanges with timber sleepers.

The only disadvantage of these spikes is that due to wave motion of rail the spike is driven out of the sleepers which reduce the pressure on the foot of F.F rails, resulting in creep occurrence.

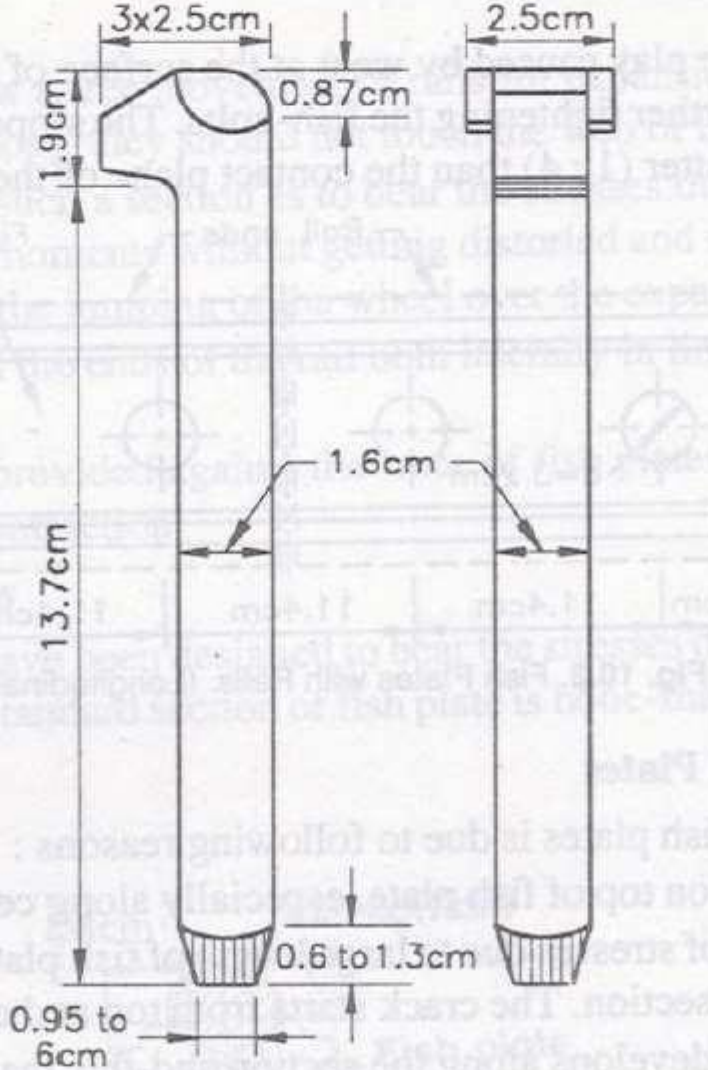


Fig. 10.4. Dog Spike.

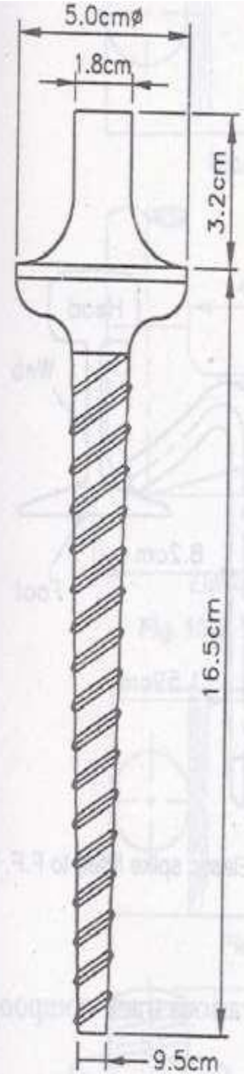


Fig. 10.5. Screw Spike

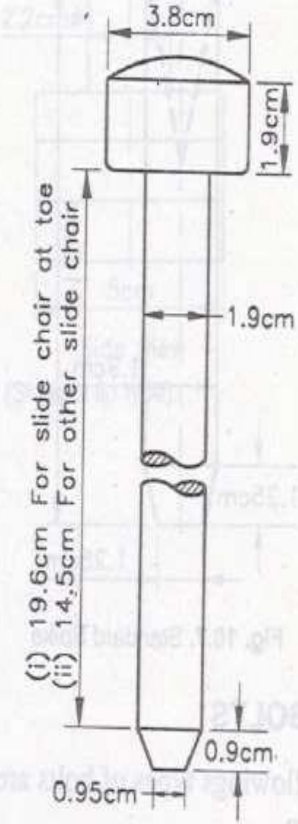


Fig. 10.6. Round Spikes

2. Screw spikes: these are tapered screws with V-threads used to fasten the rails with timber sleepers.

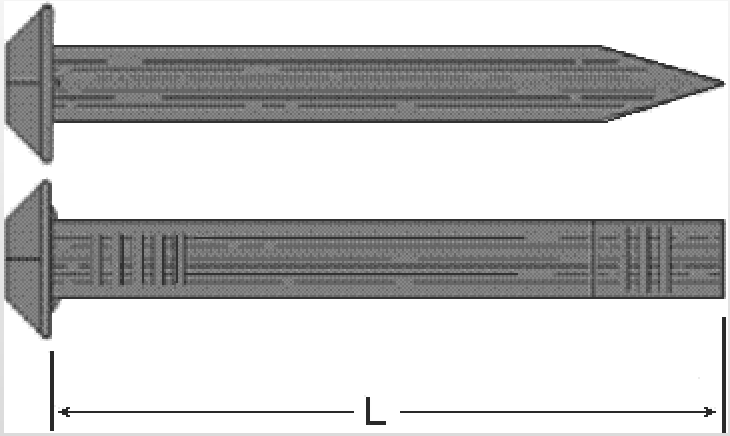
These are more stronger than dog spikes in holding power.

These are costly and the gauge maintenance is more difficult than earlier one.

Round spikes:

The head shape is either cylindrical or hemi spherical.

These are used for fixing chairs of B.H. rails to wooden sleepers and also fixing slide chairs of points and crossing.



Standard spikes:

These are used for cast iron chairs only to fix them with timber sleepers.

Elastic spikes:

The disadvantages of dog spikes can be eliminated by this. The advantages of this spikes is its head absorbs the wave motion without getting loose.

Chairs:

These are used for different types of rails

C.I Chairs:

For holding D.H and B.H rails, chairs are used. B.H rails are supported on C.I Chairs fixed to the sleepers by round spikes.

Slide chairs:

These are plates of special shape on which the stock and tongue rails rest.

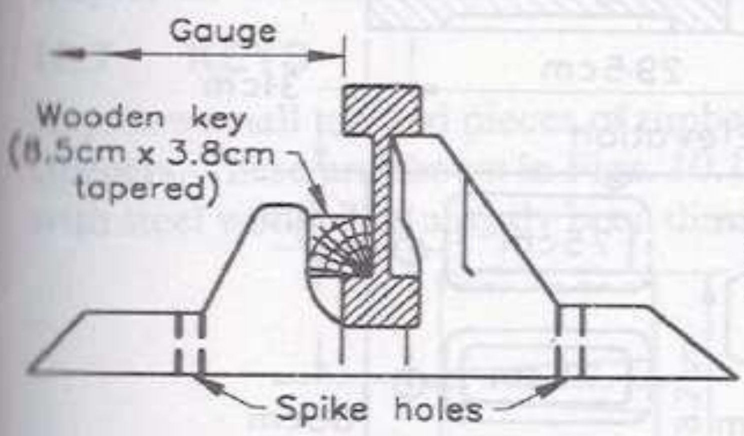


Fig. 10.13. C.I. Chair with Wooden Keys.

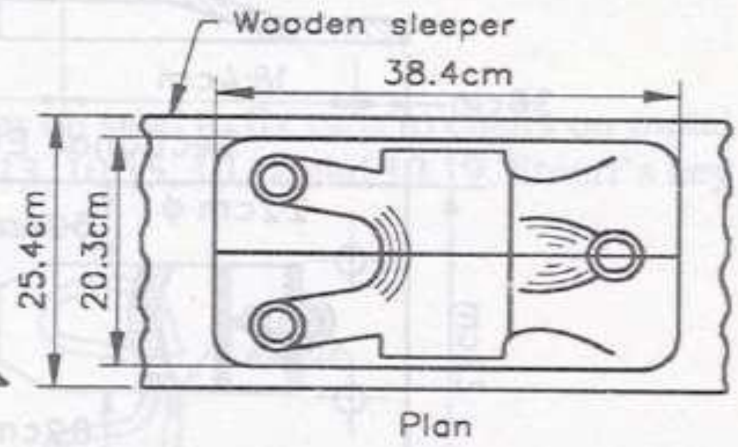


Fig. 10.14. C.I. Chair (Plan)

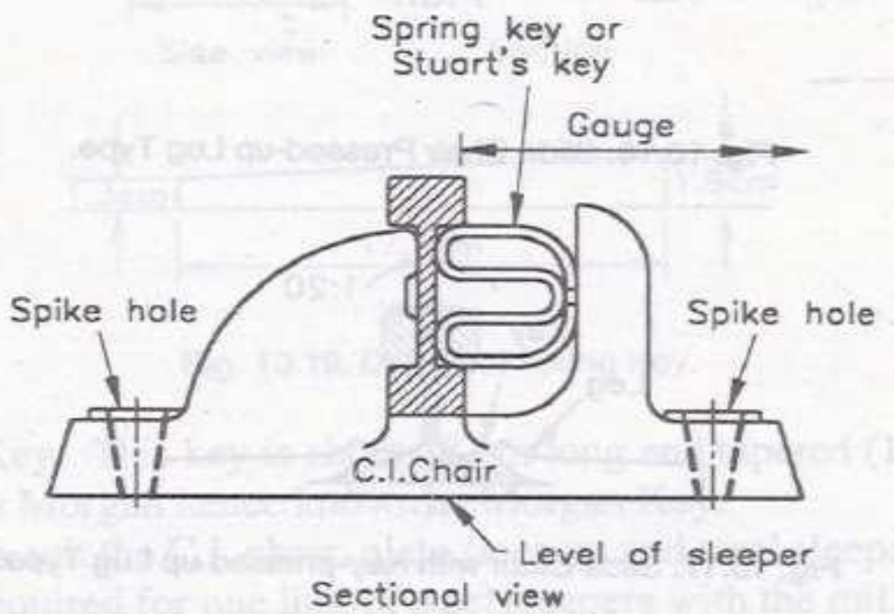


Fig. 10.15. Cast Iron Chair with Spring Keys.

Blocks: when two rails run very close as in case of check rails, etc. small blocks are inserted in between the two rails and bolted to maintain the required distance.

Bolts: used for fixing various track components in position.

Dog or hook bolt: when sleepers rest directly on girder they are fastened to top flange top flange of the girder by bolts called dog bolts.

Fish bolt: made up of medium or high carbon steel.

For a 44.7 kg rail, a bolt of 2.5 cm. dia. and 12.7 cm length is used. With each fish plate standard practice is to use four bolts. Generally, a projection of 6 mm of the shank is left out after the nut is tightened.

Keys:

Keys are small tapered pieces of timber on steel to fix rails to chairs on metal sleepers.

Morgan key:

This is about 18 cm long and tapered 1 in 32. these are suit the C.I chair, plate sleepers and steel sleepers with the rail.

The advantages of morgan keys are

- They can be used as left hand or right hand keys.
- They are light in weight due to double recess on either side.
- They are versatile in nature.

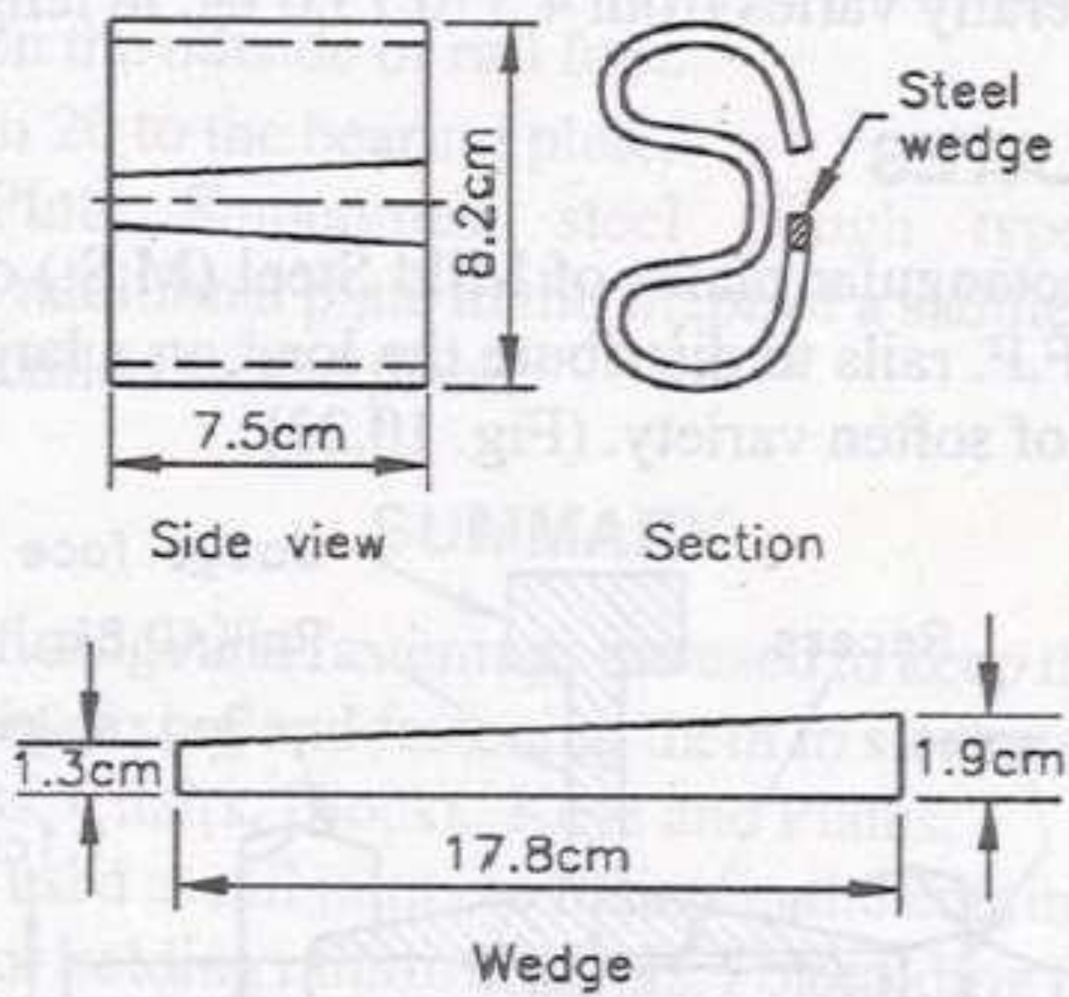


Fig. 10.19. Details of Spring Key.

Bearing plates:

Bearing plates are rectangular plates of mild steel or cast iron used below F.F rails to distribute the load on larger area of timber sleeper.

Advantages:

- To distribute the load coming on rails to the sleepers over a larger area and to prevent skidding of the rail in the soft wooden sleepers.
- Prevent the destruction of the sleeper due to rubbing action of the rail.
- Adzing of sleeper can be avoided by bearing plates.

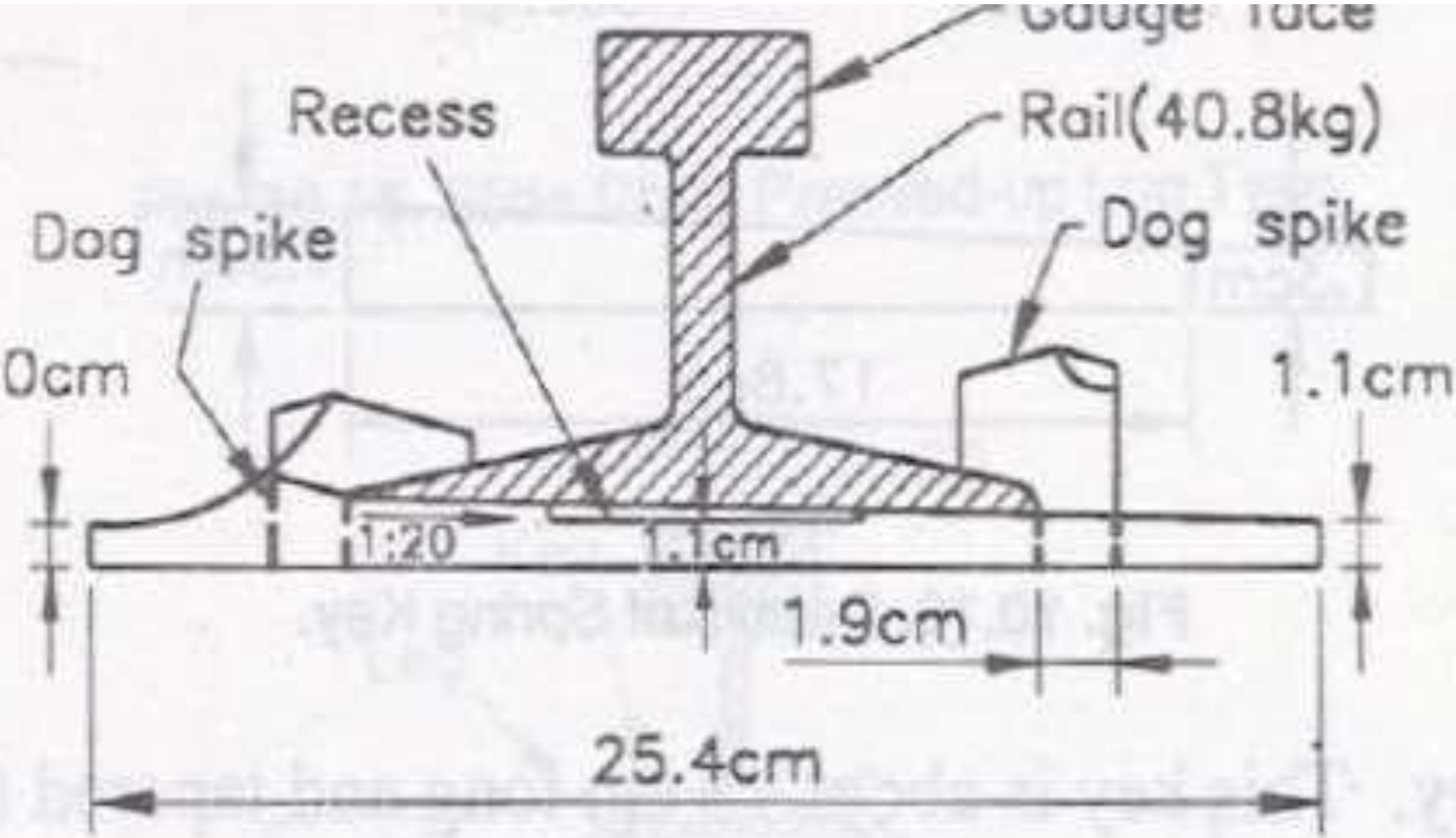


Fig. 10.23. Bearing Plates for F.F. Rails.

|| JAI SRI GURUDEV ||

BGSIT

DEPARTMENT OF CIVIL ENGINEERING

Railways, Harbour, Tunneling & Airports

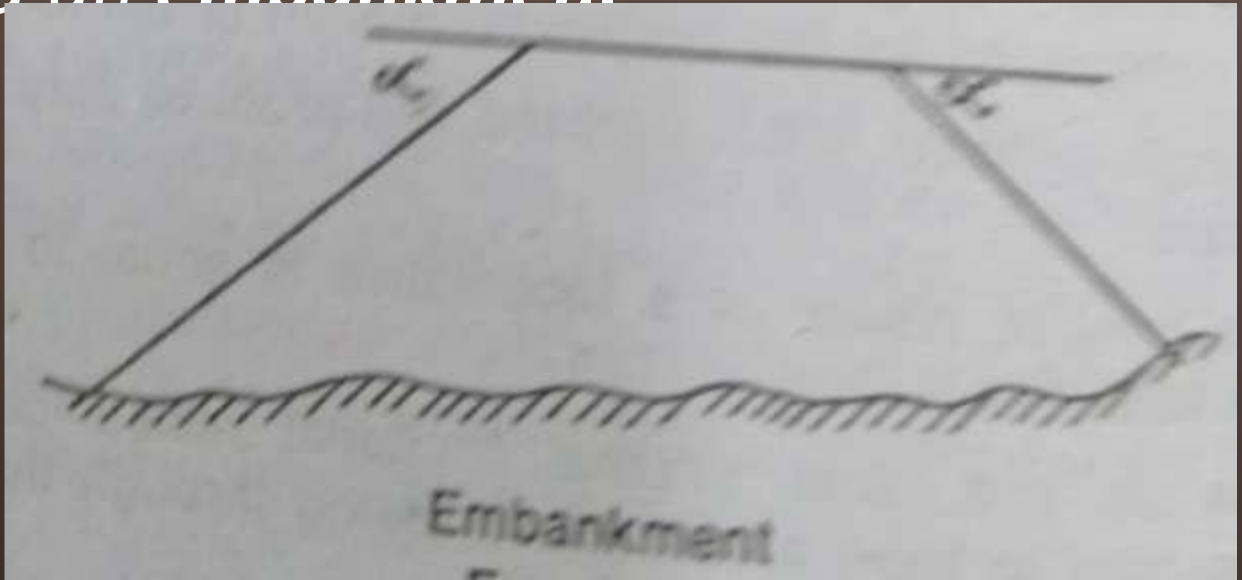
MODULE 2

RAILWAY CONSTRUCTION & MAINTENANCE

EARTHWORK

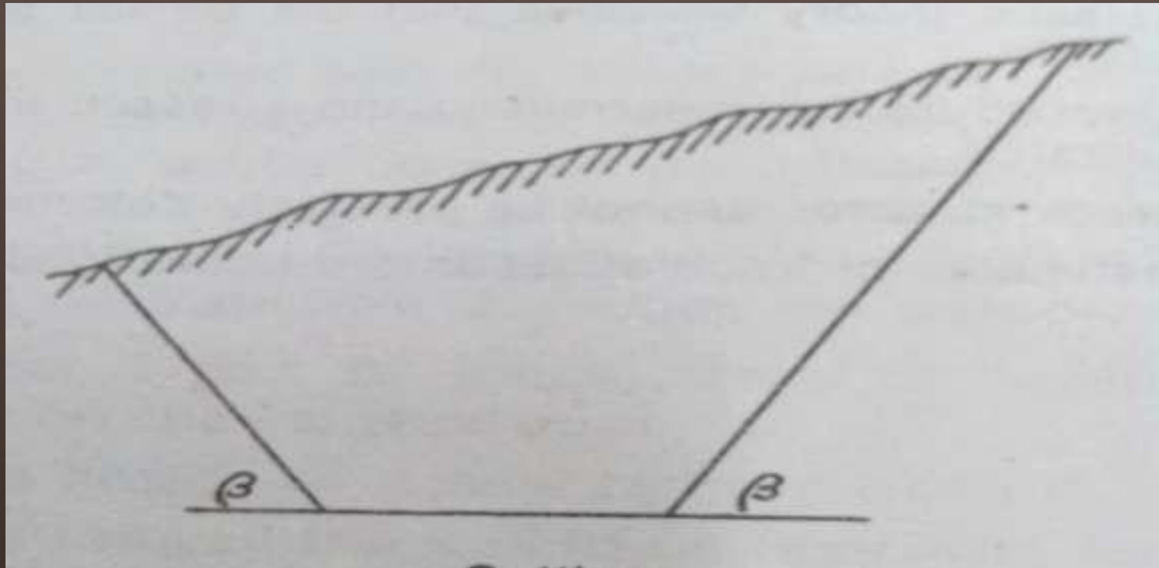
Usual forms of cross-sections:

- *The naturally occurring soil is known as the subgrade and when it is prepared to receive the ballast and track, it is called the* ***formation****.*
- *When the formation is raised on bank of earth, it is called an* ***embankment****.*



EARTHWORK

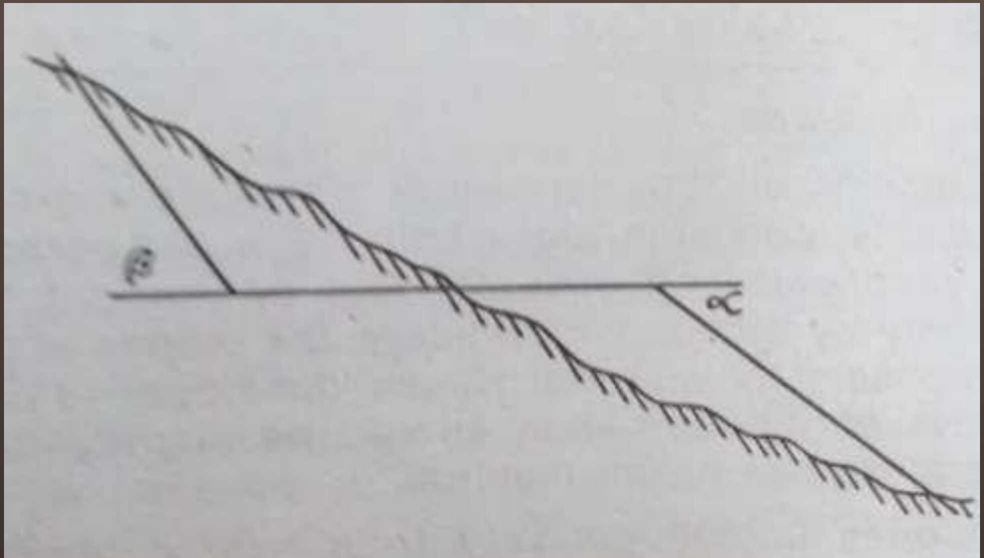
- *When it is made after cutting the ground below ground level, it is called in **cutting**.*
- *In case of cutting, the line is laid below ground level and hence, the required portion is to be excavated.*



Cutting

EARTHWORK

- *A railway line may be constructed either in embankment or in cutting or in a* ***combined section.***
- *It should be noted that angles* ***α*** *and* ***β*** *are not necessarily the same.*



Embankment and cutting

EARTHWORK

Features of railroad bed level:

When the formation is to be made on embankment or cutting, various features should be carefully considered.

1. ***Width of formation:***
   - ✓ *The width of formation will depend on:*
     - *the number of tracks,*
     - *gauge of tracks,*
     - *centre to centre distance between the tracks,*

EARTHWORK

- *Width of ballast layer*
- *Width of trenches to drain off water, if necessary.*

✓ *The width of formation is normally kept sloping from the centre for drainage purposes.*

EARTHWORK

The minimum widths of formation recommended for different gauges are shown in table:

Gauge	Minimum width of embankment		Minimum width of cutting		Remarks
	Single	Double	Single	Double	
Broad Gauge (B.G)	610 cm	1082 cm	549 cm	1021 cm	122 cm extra width is to be provided in case of the formation in cutting for the side drains.
Metre Gauge (M.G)	488 cm	884 cm	427 cm	827 cm	
Narrow Gauge (N.G)	370 cm	732 cm	335 cm	701 cm	

EARTHWORK

2. Slopes of sides:

- *The stability of the earthwork depends mainly on two factors, namely, **cohesion** and **friction**.*
- *For **temporary stability**, **cohesion** is useful and reliable,*
- *But **permanent stability** is achieved only by **friction** which keeps the slopes at the natural angle of repose of the material.*
- *The slopes to be provided to the sides of the formation should be slightly flatter than the angle of repose of the material.*

EARTHWORK

- *The slopes in cuttings vary from nearly vertical to **1.5 to 1** or steeper.*

3. Drains:

- *The accumulation of water reduces the friction in all sorts of soils.*
- *In case of embankments, the rain water is easily drained off. But in case of cuttings, drains are to be provided.*
- *The side drains are constructed along the track at a depth of about 1200 mm from the rail level.*

EARTHWORK

- *The size of drains will depend on the quantity of water to be drained.*
- *Sometimes, pipes of stoneware or concrete are laid in a trench with open or half open joints and covered with porous material.*

EARTHWORK

Stabilization of track on poor soil:

Following are four usual methods of stabilization of track on poor soil:

i. ***Layer of moorum***

ii. ***Cement grouting***

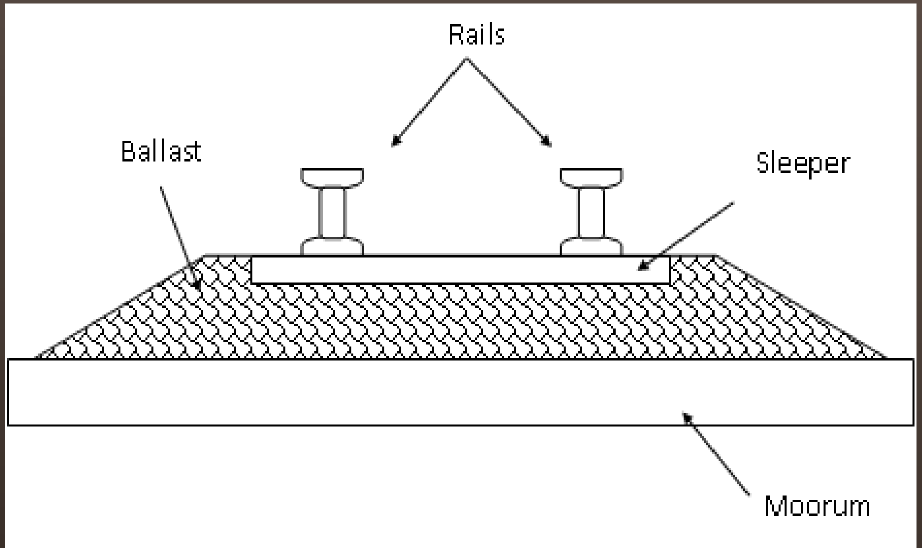
iii. ***Sand piles***

iv. ***Use of chemicals***

EARTHWORK

i. ***Layer Of Moorum:***

- *In very poor soil such as black cotton soil which swells and shrinks considerably by contact with moisture and by the loss of moisture to the extent of 20% to 30% of its volume, a layer of moorum is provided under the ballast, as shown:*



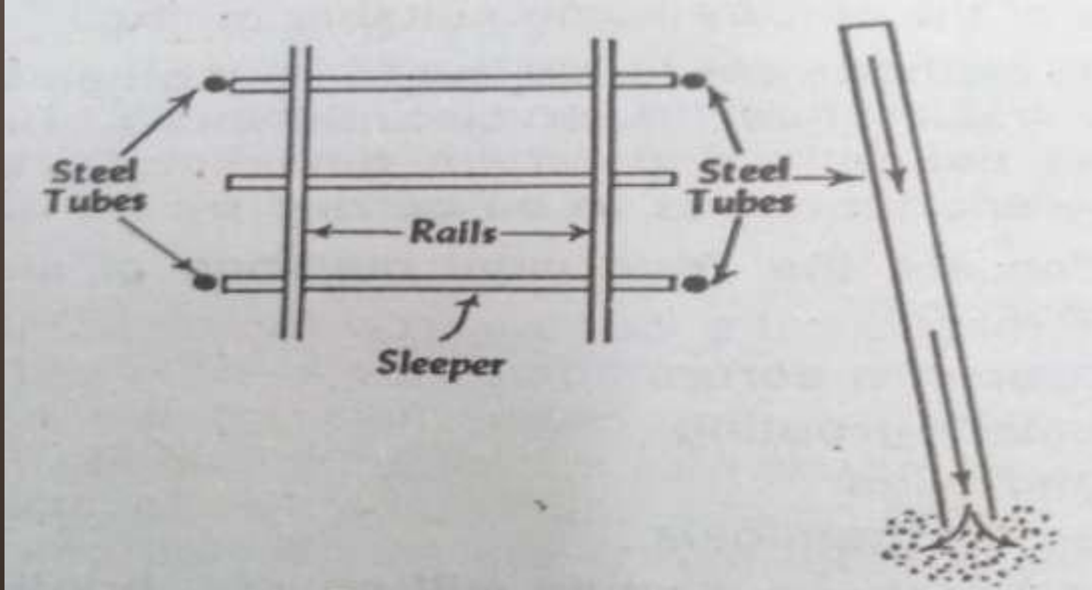
EARTHWORK

- *The thickness of this layer varies from 300 mm to 600 mm.*
- *This layer distributes the pressure and it also prevents the ballast from being lost in the cracks of the soil.*
- *Instead of moorum, ashes, rubble, slabs of concrete, unserviceable sleepers, etc. are also used and they are found to be quite satisfactory.*

EARTHWORK

ii. Cement Grouting:

- *In this method, the steel tubes about 30 mm diameter are driven into the formation at every alternate sleeper.*
- *They are driven near the ends of the sleepers as shown:*



Cement grouting

EARTHWORK

- *The steel tubes are generally 150 cm long and driven at an angle so that the end of the tube is nearly under the rail.*
- *Then the cement grout is forced under a pressure of about 0.7 N/mm2 through these tubes.*
- *The cement grout spreads through the poor soil and consolidates it.*
- *The steel tubes are then gradually taken out.*

EARTHWORK

iii. Sand Piles:

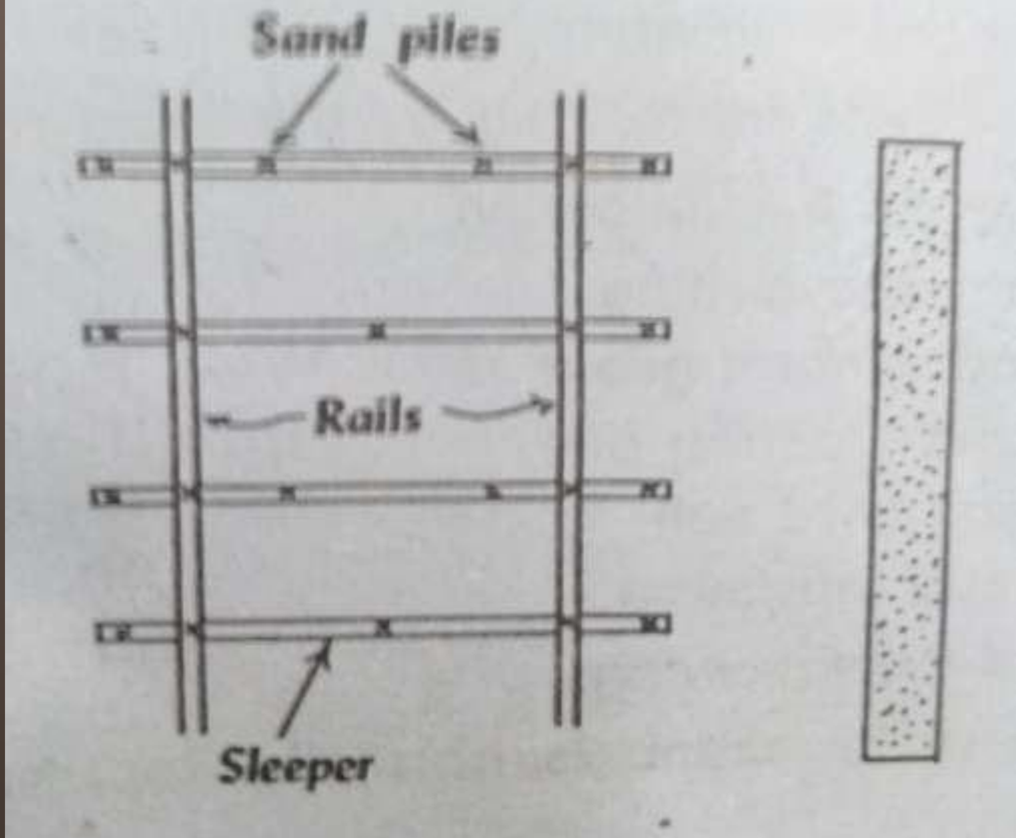
- *In this method, a vertical bore of about 300 mm diameter is made in the ground by driving wooden pile;*
- *The wooden pile is then withdrawn and the space is filled with sand and is well-rammed;*
- *The functions performed by the sand piles are as follows:*

a. They can function as timber piles.

b. They provide an arrangement of vertical drainage. c.

They provide good mechanical support.

EARTHWORK



Sand piles

EARTHWORK

iv. Use Of Chemicals:

- *In this method, the chemicals are used in place of cement grout to consolidate the soil;*
- *The silicate of soda followed by calcium chloride is effective for sandy soils containing less than 25% clay and silt.*

METHODS OF CONSTRUCTION

1. **Telescopic Method of Construction**
2. **Trame line Method of Construction**
3. **Mechanaical Methods**

1.TELESCOPIC METHOD OF CONSTRUCTION

In this method of construction rails, sleepers, fastenings are unloaded from the material train as closer to raill head as possible. The sleepers are carried by cart or by men along the adjoining service road and spread on the ballast. The rails are then carried on pairs to the end of last pair of connected rails and linked

2.TRAME LINE METHOD OF CONSTRUCTION

This method is used where tram carrier are installed for carrying earthwork or in rainy season due to difficulty in movement of cart.

The basic difference between Telescopic and Trame line lies in the conveyance and spreading of sleepers.

3.MECHANAICAL METHODS

- This method is extensively used in Britain and America by using special track laying machine. There are two types of machines available

1. In the first type track material carried by the material train and delivered at rail head and laid in the required position by means of projecting arm mounted on the truck nearest to the rail head. The material train moves forward on the assembled track and operation repeated.

MECHANICAL METHOD

- **In the second method a long cantilevered arm projecting beyond fitted on the wagon. A panel of assembled track consisting pair of rails with number of sleepers on the ballast layer. This panel is carried by special trolley running over the wagons of material train to the jibs. It is lowered by the jib at the required position and connected to the previous panel. The train moves on and operation repeated.**

MAINTENANCE OF RAILWAY TRACK

-Existing System of track Maintenance

1.Manually

2. Three tier system of maintenance

The track should be maintained either by conventional system of track maintenance or by three – tier system of track maintenance.

In both the systems, track requires to be overhauled periodically with the object of restoring it to best possible condition, consistent with its maintainability. Periodicity of

overhauling depends on several factors, such as type of track structure, its age, volume of

traffic, rate of track deterioration, maximum permissible speed, system of traction, condition

TRACK MAINTENANCE

(A) Conventional system of track maintenance- in this track is maintained manually

(B) Three tier system of track maintenance: -

(1) 3-tier system of track maintenance shall be adopted on sections nominated for mechanized maintenance. This shall consist of the following 3 tiers of maintenance-

(i) On track machines

(ii) Mobile maintenance units

(iii) Sectional gangs

TRACK MAINTENANCE

(2) Large track machines for track maintenance include tie- tamping machines for plain track and points and crossings, shoulder ballast cleaning machines, ballast-cleaning machines, ballast regulating machines and dynamic track stabilizers.

These machines shall be used as per the various instructions issued in Indian Railways Track Machines Manual.

These machines shall be deployed to carry out the following jobs.

(a) Systematic tamping of plain track as well as points and crossings

(b) Intermediate tamping of plain track as well as points and crossings

(c) Shoulder ballast cleaning

(d) Ballast profiling / redistribution

TRACK MAINTENANCE

(e) Track stabilization

(f) Periodical deep screening

(3) Mobile Maintenance Units-

(a) The mobile maintenance units (MMU) shall consist of two groups-

(i) MMU-I one for each PWI's section

(ii) MMU-II one for each sub division

(b) The functions of MMU shall be as below:

TRACK MAINTENANCE

- 3. Track Relaying Activities and Existing system of Relaying
  - Track relaying activities involves following activities:
- 1.Plain track relaying viz.CTR, TRR and TSR 2.Turnout relaying
  - At present both these activities are performed both manually and by machines.

MODERN METHODS OF MAINTENANCE

The following are the main modern methods of track maintained:

- Mechanized Maintenance or Mechanical Tamping
- Measured Shovel Packing
- Directed Track Maintenance

MECHANISED MAINTENANCE

- It makes use of track machines namely tampers for day to day track maintenance
- This method is relatively more effective, economical, and efficient to cater the needs of high
- speed and heavier axle loads. Methods of Mechanical Tamping
- Off -Track Tamping
- On- Track Tamping Off-Track Tamping
- Off-track tampers which are portable & can be taken off the track within a short period of time are used.
- They work in pairs from opposite sides of the sleepers diagonally under the rail seat to ensure maximum consolidation of the ballast.
- It requires no blocking of the traffic

DEMERITS

- Maintenance of tampers is difficult
- High standard of maintenance cannot be achieved
- Intensive supervision is needed
- Transportation of tampers with power unit is difficult

Types of Off-Track Tampers

- Self-contained Percussion type Vibratory type
- Off-track tampers worked from a common power unit On- Track Tamping
- On-track tampers which are self-propelled vehicles are used to tamp the sleepers automatically through various controls provided in the operator's cabin
- These are superior to off-track tampers in respect of control, efficiency, quality of work and retention of tamping.
- Automatic aligning, lifting, cross and longitudinal levelling and packing are simultaneously possible
- Types of On- Track Tampers
- Light On- Track Tampers
- Heavy On- Track Tampers

MEASURED SHOVEL PACKING

In this method, the track defects like unevenness and voids are accurately measured, the track is lifted by means of jacks and measured quantities of small broken stone chippings are placed under the sleeper, to bring the track to the predetermined level.

Merits

- No traffic block is needed for carrying out maintenance job
- More output
- Less materials are needed
- Packing retentively of fish joined sleepers is more
- Less tedious

Demerits

- Suitable for only flat bottom sleepers like wooden & concrete
- Special sized stone chipping may not be readily available
- Even for daily maintenance skilled labour is needed
- Cannot be used for newly screened track

Applications of M.S.P

- Maintenance of flat bottom wooden sleepers
- Packing of joint wooden sleepers in metal sleeper track
- Through packing of turnouts
- Defogging of the hogged rail ends

DIRECTED TRACK MAINTENANCE (D.T.M)

It is a method to maintain the track as directed by day-to-day requirements but not as prescribed routine.

- It is also called Track Maintenance System or TMS
- **It consists of 3 stages:**
- Proper identification of defects in track geometry by means of measuring and recording devices
- Rectification of these defects only at indicated locations in order to maintain the track to predetermined standards
- Checking the quality of work and output by the supervisor in charge of maintenance

Objectives of D.T.M

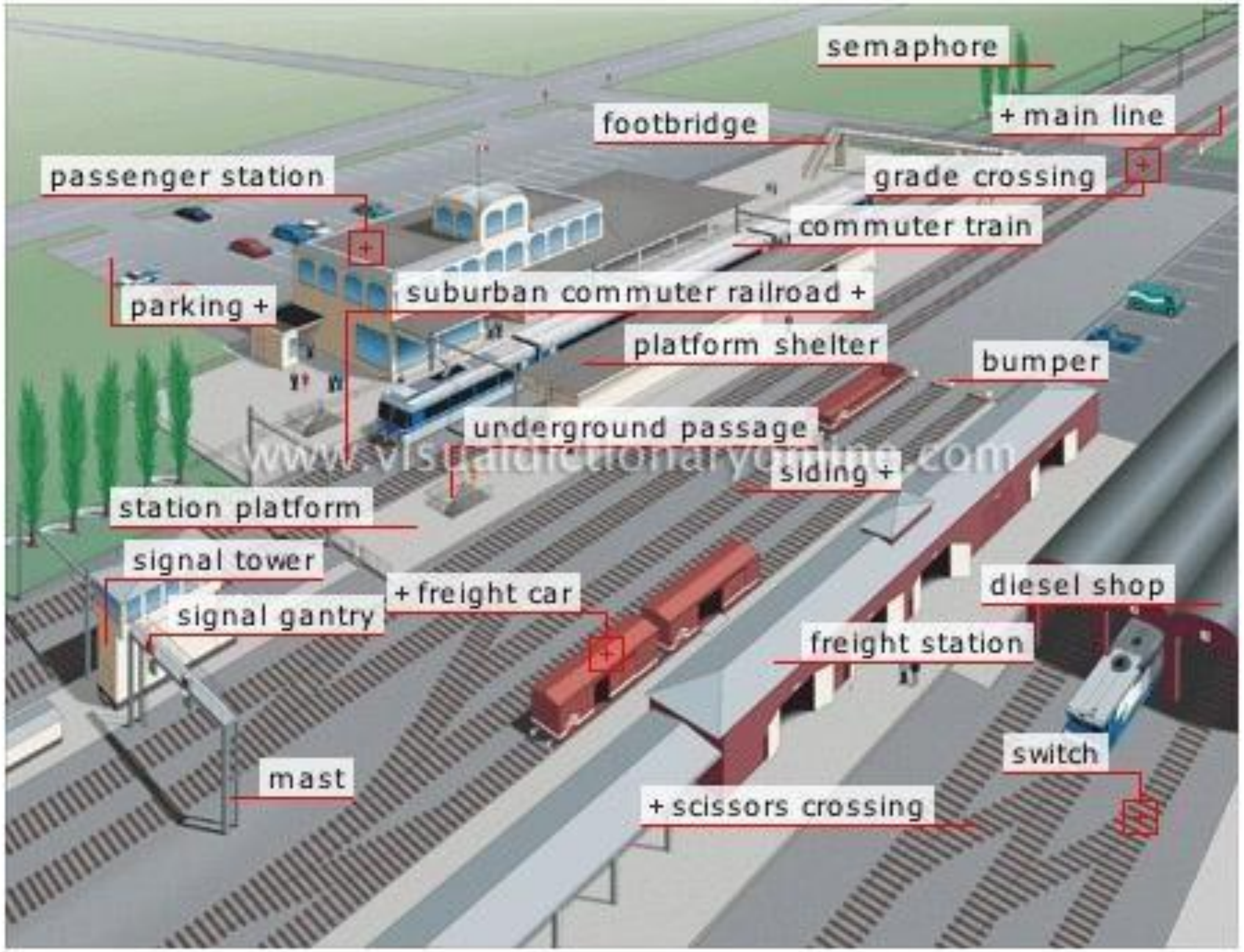
- To maintain the track to a high standard of maintenance as per the prescribed tolerances
- To achieve economy in maintenance by avoiding unnecessary work involving men and materials

STATION AND YARDS

Definition of Station

- A railway station or a railroad station and often shortened to just station, is a railway facility where trains regularly stop to load or unload passengers and/or freight

STATION AND YARDS



PURPOSE OF RAILWAY STATION

- For exchange of passengers and goods.
- For control of train movements
- To enable the trains on a single line track to cross from opposite directions.
- To enable the following express trains to overtake
- For taking diesel or coal and water for locomotives
- For detaching engines and running staff
- For detaching or attaching of compartments and wagons
- For sorting of bogies to form new trains, housing of locomotive in loco sheds.
- In emergencies in ease of dislocation of track due to rains, accidents etc...
- For repairing engines and changing their direction
- Railway station are having suitable approach roads from surrounding areas.

TYPES OF STATIONS

- Wayside Stations, Junction Stations, Terminal Stations

Functional Classification of Stations: The layout of stations varies in size and importance according to the type and volume of traffic handled and according to their locations with respect to cities or industrial areas. Broadly speaking, the layouts required for passenger stations and their yards can be divided into the following categories for the purpose of study.

- Halts
- Flag stations
- Roadside or crossing stations
- Junction stations
- Terminal stations

WAYSIDE STATIONS

- In this type arrangements are made for crossing or for overtaking trains. Wayside stations are of the following types.
- i.Halt stations, ii.Flag Stations, iii.Crossing stations

HALT STATIONS

- A **halt**, is a small station, usually unstaffed and with few or no facilities. In some cases, trains stop only on request, when passengers on the platform indicate that they wish to board, or passengers on the train inform the crew that they wish to alight.

HALT STATIONS

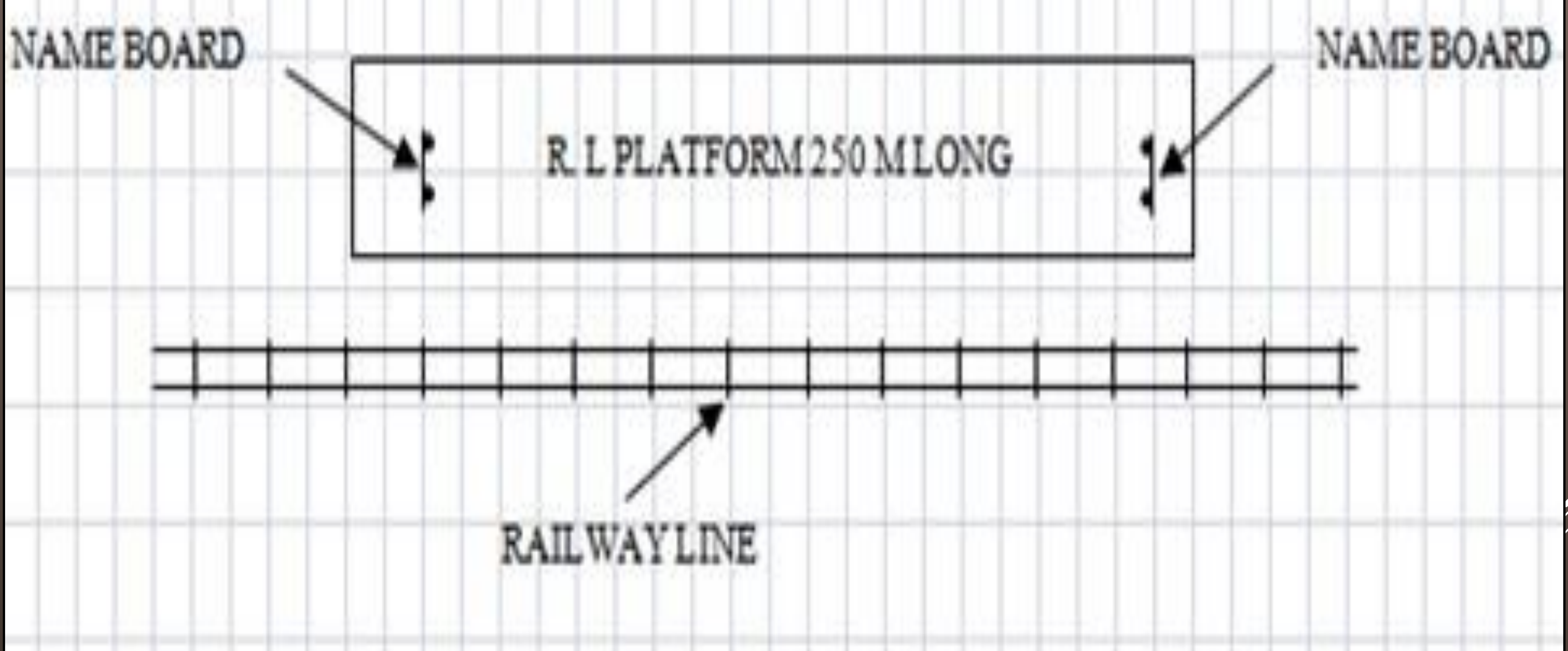


Fig : LAYOUT OF HALT STATION

FLAG STATIONS

- **Flag stations** describes a stopping point at which trains stop only on an as-need or request basis; that is, only if there are passengers to be picked up or dropped off.
- These stations have no overtaking or crossing facilities and arrangements to control the movement of trains. These stations have buildings, staff and telegraph facilities.
- Some of the flag stations have sidings also in the form of loops.

FLAG STATIONS

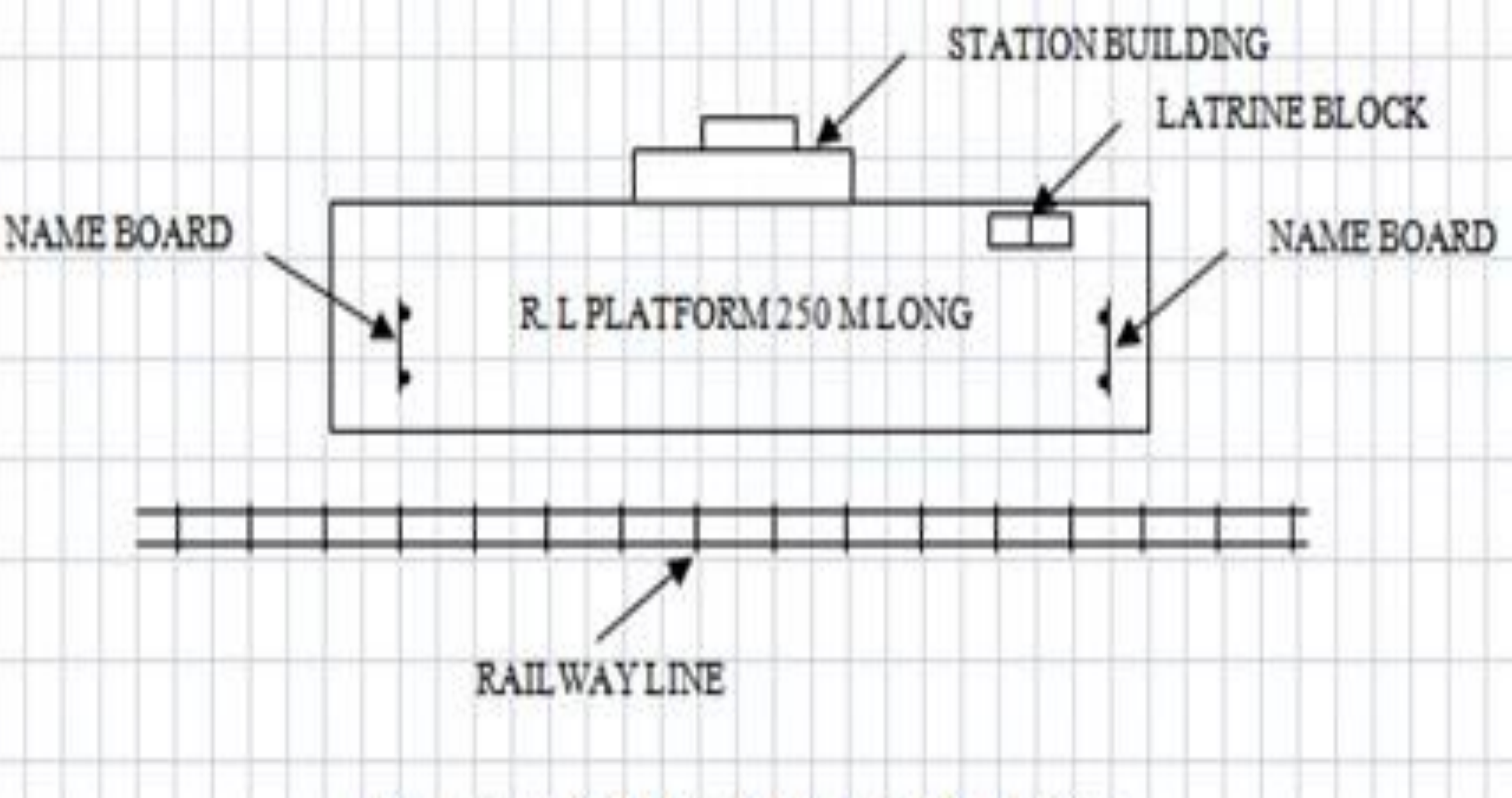


Fig : LAYOUT OF FLAG STATION

CROSSING STATIONS

- Provided with facilities for crossing
- In this type at least one loop line is provided to allow another train if one track is already occupied by a waiting train
- Generally the train to be stopped is taken on the loop line and the through train is allowed to pass on the main line

CROSSING STATIONS

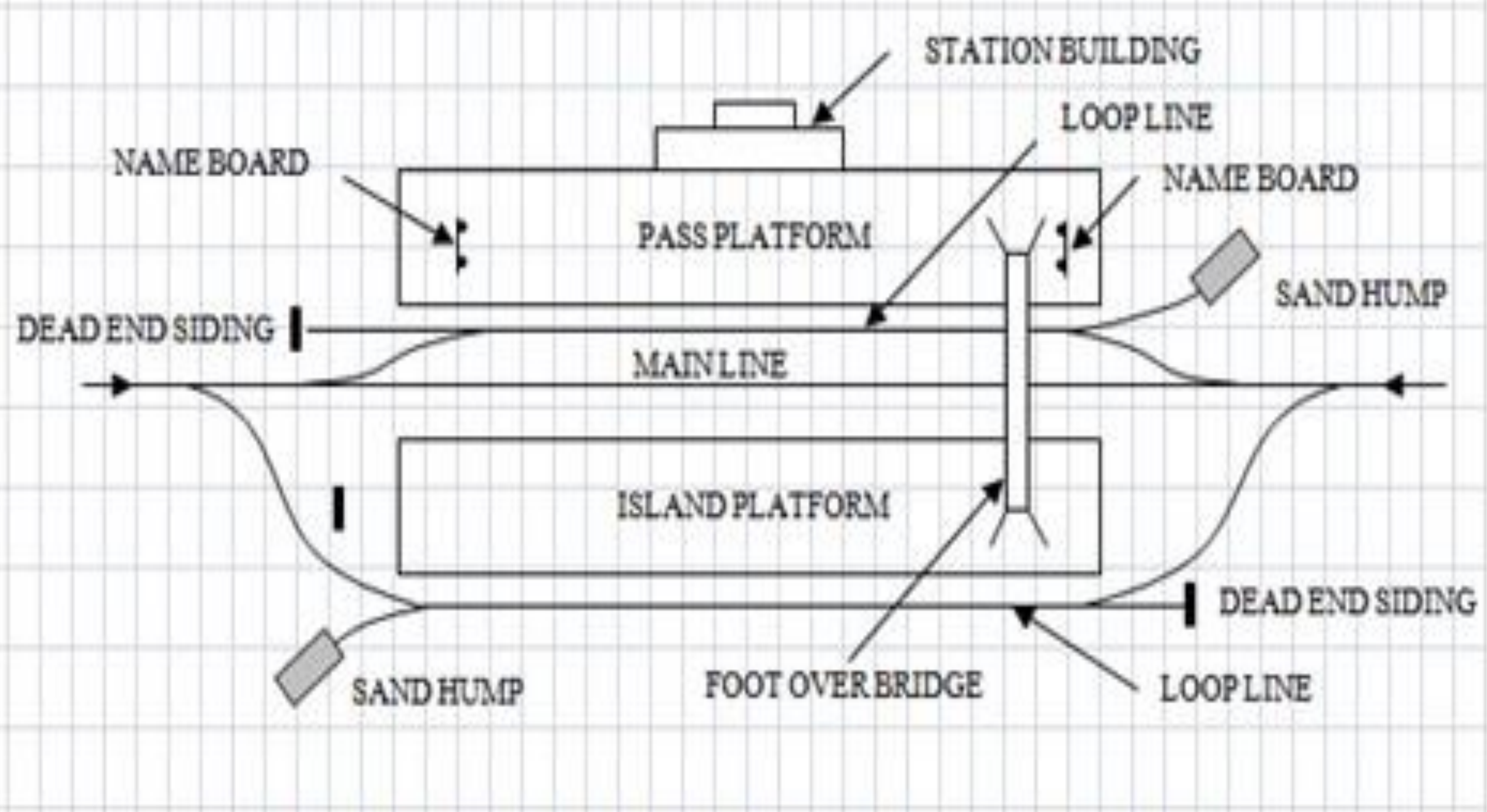


Fig : LAYOUT OF ROAD SIDE OR CROSSING STATION

JUNCTION STATIONS:

- At a junction stations, lines from three or more directions meet
- The stations where a branch line meets the main line are known as junctions.

Arrangements in junction stations

- Facilities for interchange of traffic between main and branch line
- Facilities to clean and repair the compartments of the trains
- Facilities for good sidings, engine sheds, turn table etc.

JUNCTION STATIONS:

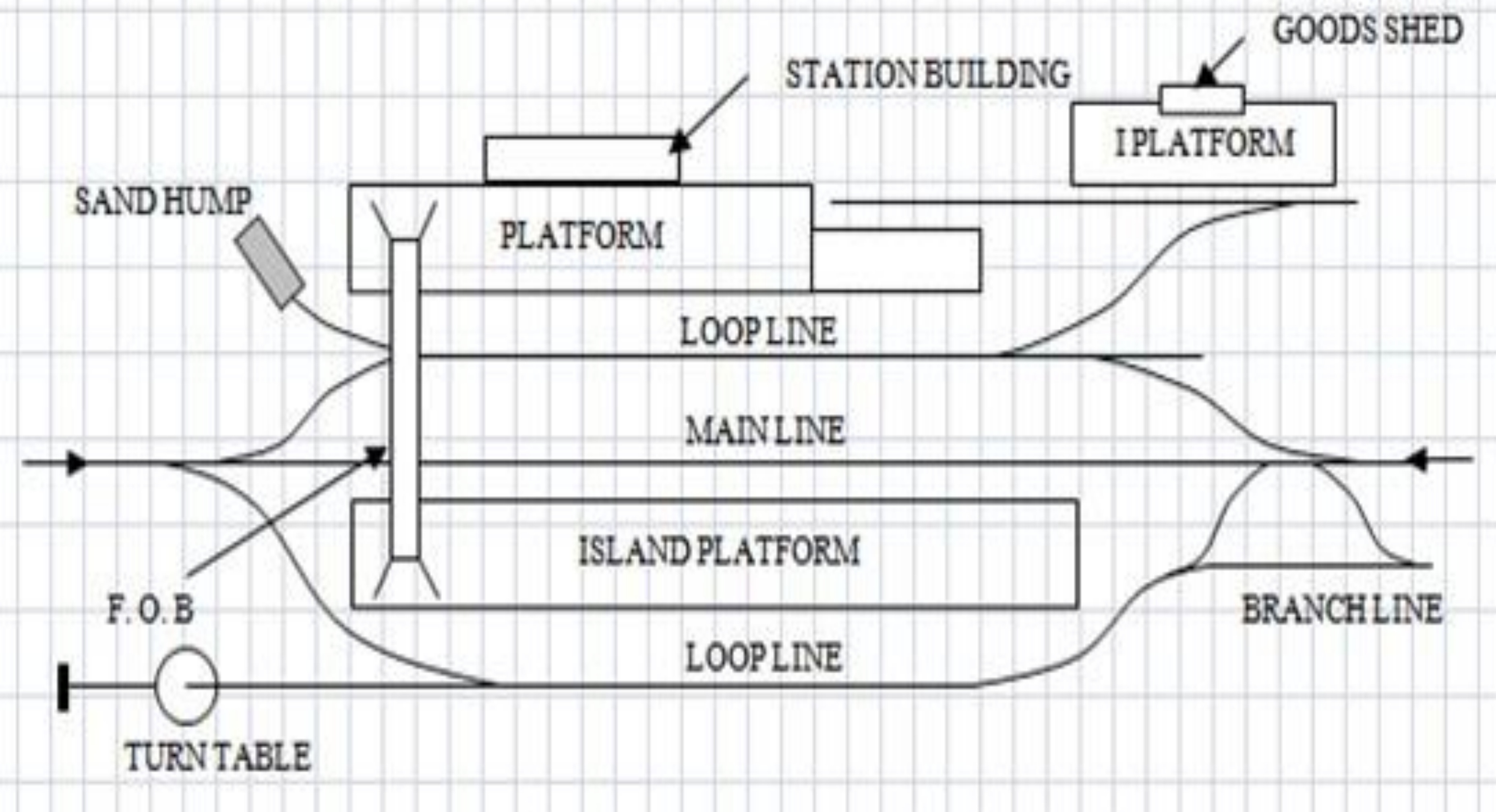


Fig : LAYOUT OF JUNCTION STATION

TERMINAL STATIONS:

- It is a station where a railway line or one of its branches terminates
- **Facilities required in terminal stations**
- Watering, coaling, cleaning, servicing the engine
- Turn table for the change of direction of the engine
- Facilities for dealing goods traffic. Such as marshalling yard, engine sheds, sidings etc.
- In circulating area, ticket office, restaurant etc are provided and it is directly connected to the road

TERMINAL STATIONS:

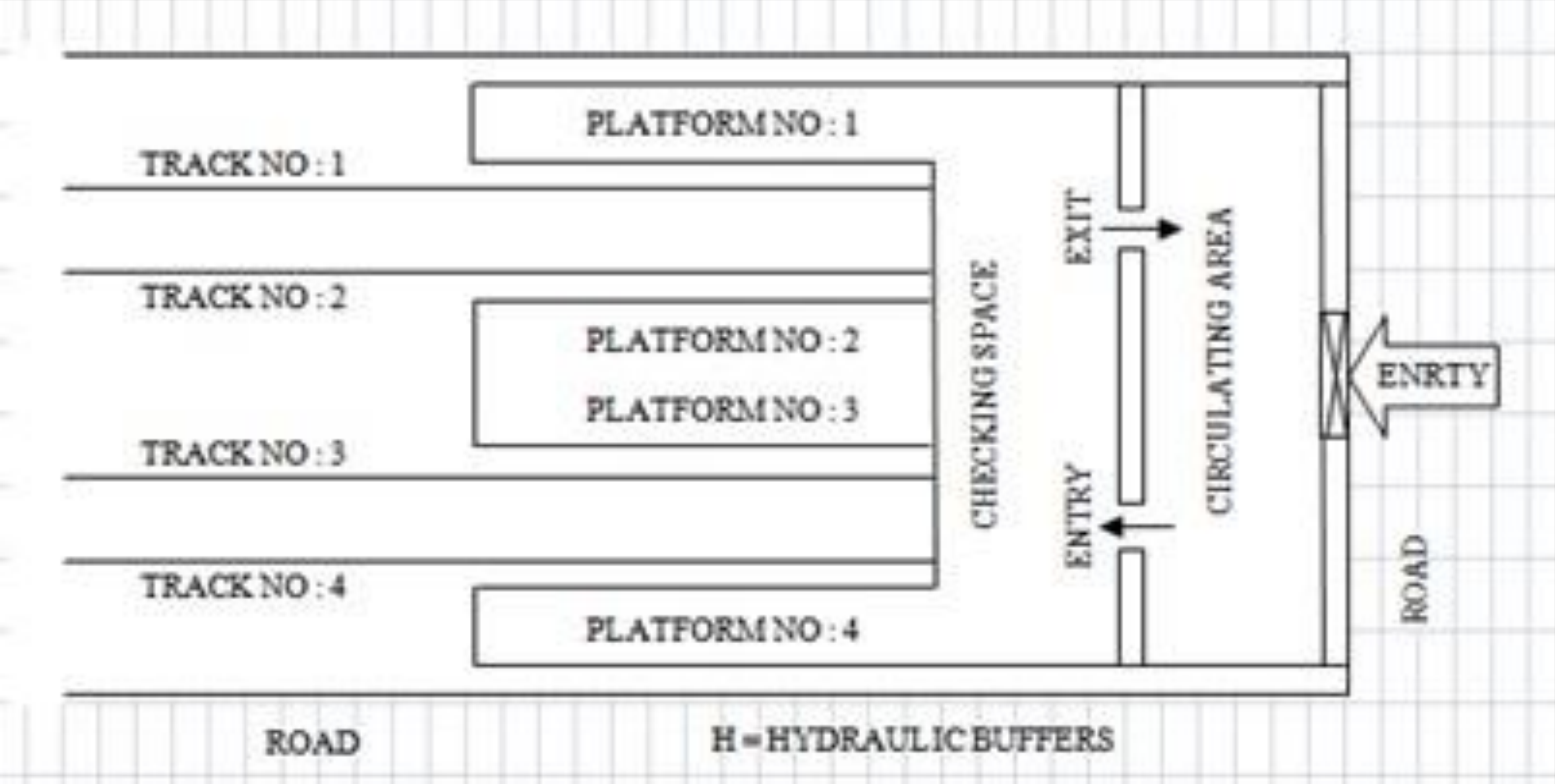


Fig : LAYOUT OF TERMINAL STATION

CLASSIFICATION OF STATIONS

- Stations can be classified on the basis of their operation as
- 1.Block stations-Class A, Class B and Class C
- 2.Non Block Stations-Class D stations or Flag stations
- 3.Special class stations.

BLOCK STATIONS:

- The stations at the end the block sections are called Block stations
- Authority to proceed is given in the shape of token at these stations.

Class A Station:

- On these stations the track is cleared up to 400m beyond the home signal for giving permission to approach a train

Class B Station:

- In such stations, the other signal is provided at about 580m from the home signal

Class C Station:

- On these stations passengers are not booked. It is simply a block meant for splitting a long block section and to reduce the interval between the successive trains.

NON BLOCK STATIONS:

- Also known as Class D station or Flag station
- Situated between two consecutive block stations
- May not be telegraphically connected to the adjacent stations
- No equipment or staff is provided for controlling the movements of the trains.
- Trains are stopped by flag signals only

- A class station: A class stations are normally provided on double-line sections. At such stations a ‘line clear’ signal cannot be granted at the rear of a station unless the line on which a train is to be received is clear and the facing points set and locked. No shunting can be done after line clear has been granted.

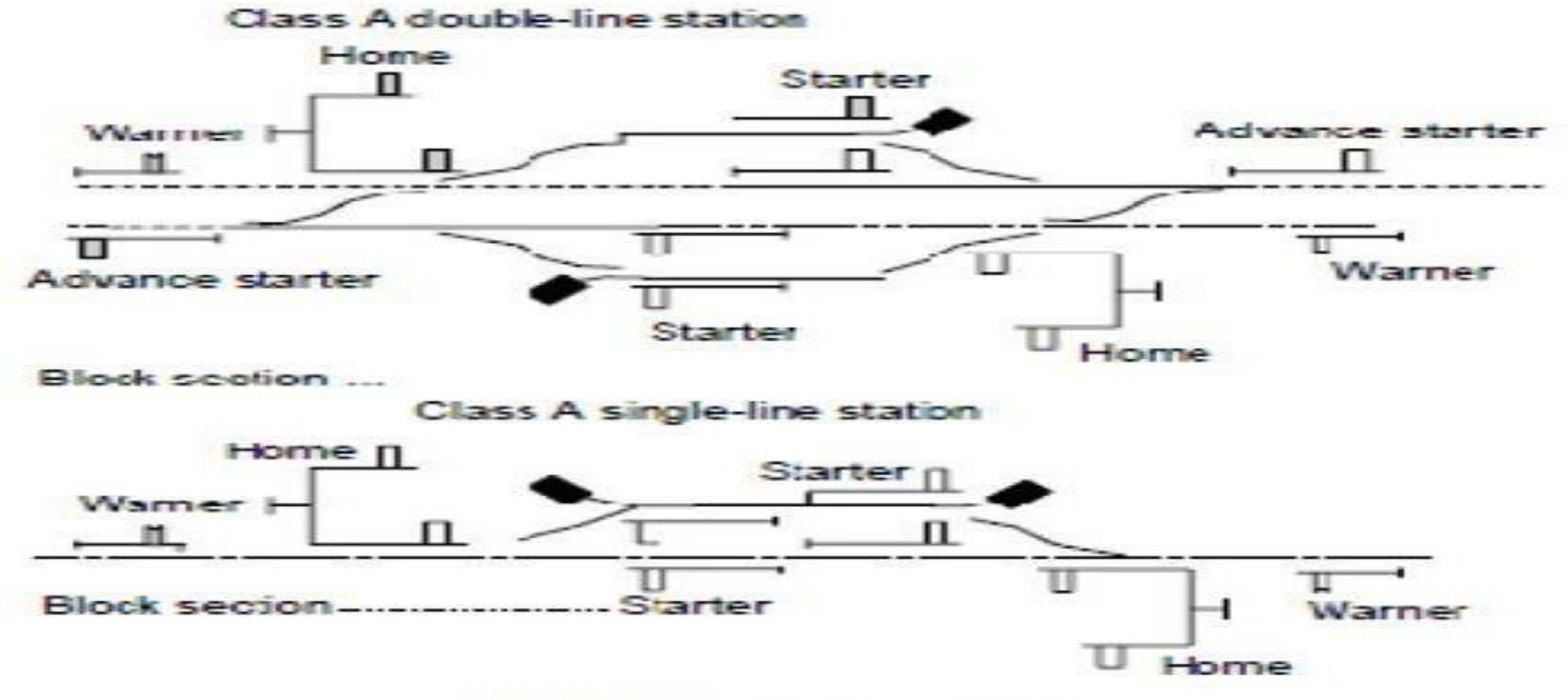


Fig. 26.1 A class station

- **B class station: This is the most common type of station and is provided on single-line as well as double-line sections. At a B class station, the line has to be clear up to an adequate distance beyond the outer signal before 'permission to approach' can be given to a train. The minimum signals required at a B class station are as follows.**

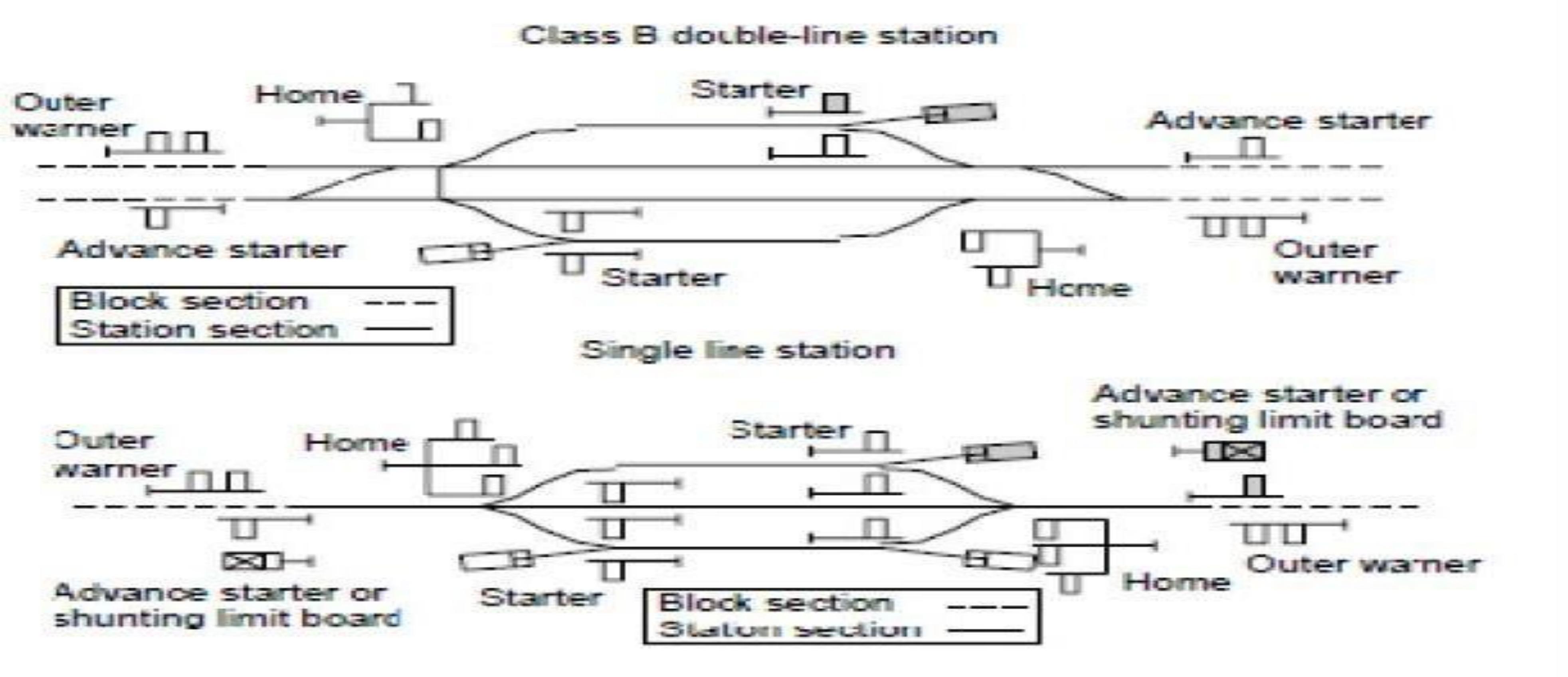


Fig. 26.2 B class station

- C class station: The C class station is only a block hut where no booking of passengers is done. It is basically provided to split a long block section so that the interval between successive trains is reduced. No train normally stops at these stations.

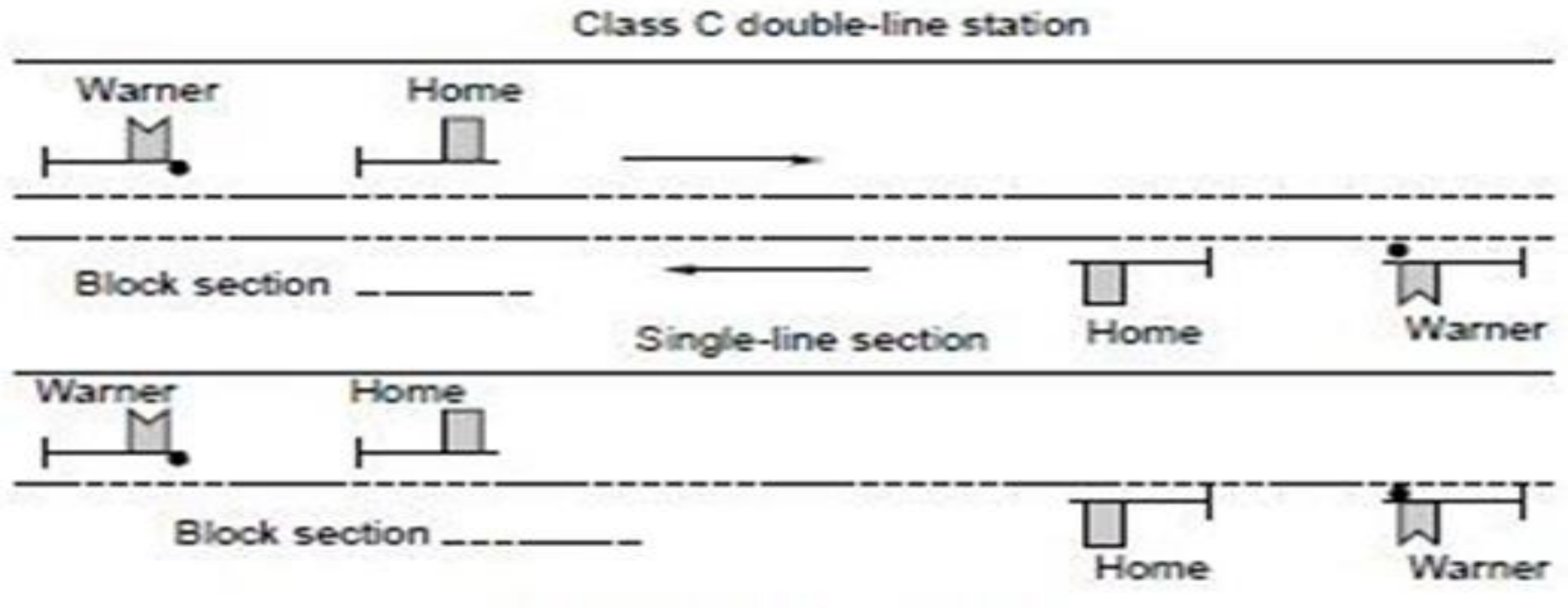


Fig. 26.3 C class station

SPECIAL CLASS STATIONS:

- Stations not coming under block station and non block stations are called special class station

PLATFORMS - PASSENGER AND GOODS PLATFORMS:

- A **railway platform** is a section of pathway, alongside rail tracks at a railway station, metro station or tram stop, at which passengers may board or alight from trains or trams.
- Almost all rail stations have some form of platform, with larger stations having multiple platforms.
- Platform types include the **bay platform**, **side platform** (also called **through platform**), **split platform** and the **island platform**.
- A bay platform is one at which the track terminates, i.e. a dead-end or siding.
- A side platform is the more usual type, alongside tracks where the train arrives from one end and leaves towards the other.
- An island platform has through platforms on both sides; it may be indented on one or both ends, with bay platforms.

PASSENGER PLATFORM

GOODS PLATFORM

DEFINITION OF YARD:

- An area consisting of a network of railway tracks, sidings, and sheds for storing, maintaining, and joining engines and carriages.
- A yard is defined as a system of tracks laid within definite limits for various purposes such as receiving sorting and dispatch of vehicles.

RAILWAY YARD

TYPES OF YARDS:

- Passenger yards, Goods yards, Marshalling yards, Locomotive yards

PASSENGER YARDS:

- Function of passenger yard is to provide all the facilities for the safe movement of passengers.

Facilities in passenger yards

- Booking office, enquiry office, luggage booking room, cloak room and waiting room for passengers
- Parking space for vehicles
- Signals for reception and dispatch of trains
- Platforms and sidings for shunting facilities
- Facilities for changing batteries
- Facilities for passing a through train
- Washing lines, sick lines facilities

PASSENGER YARDS

GOODS YARDS:

- A **goods station** (also known as a **goods yard**, **goods depot** or **freight station**) is, in the widest sense, a railway station which is exclusively or predominantly where goods (or freight) of any description are loaded or unloaded from ships or road vehicles and/or where goods wagons are transferred to local sidings.
- These are provided for receiving, loading and unloading of goods

GOODS YARDS

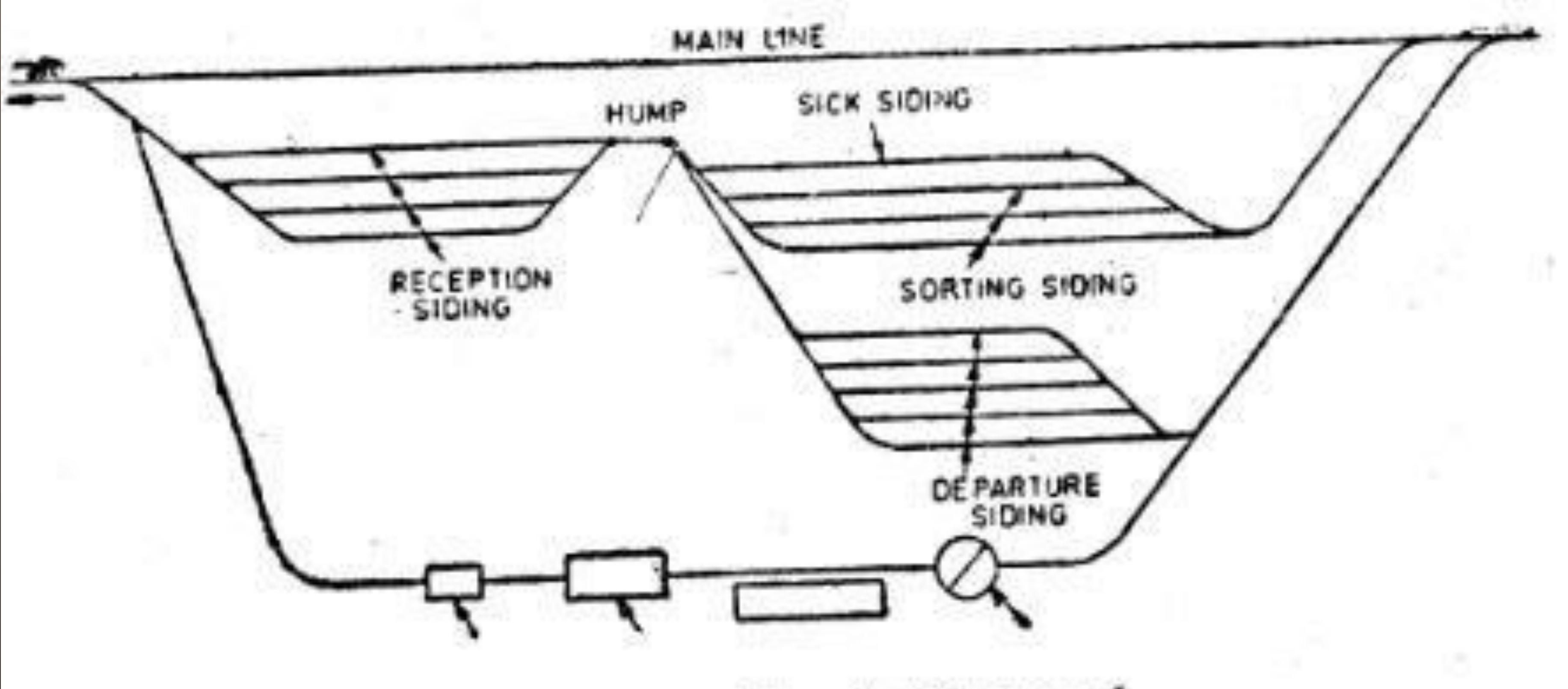
REQUIREMENTS OF A GOODS YARD

- Approach road for movement of goods
- Sufficient number of platforms for loading and unloading
- Sufficient number of godowns
- Booking office
- Cart weighing machine
- Cranes for loading and unloading
- Vacuum testing machine

MARSHALLING YARDS:

- **Marshalling yard** is a railroad yard found at some freight train stations, used to separate railroad cars on to one of several tracks
- It is the place where goods wagons received from different centres are sorted out and placed in order to detached at different stations
- The marshalling yards are distribution centres
- Empty wagons are also kept in marshalling yards

MARSHALLING YARDS:



Marshalling yard.

FACTORS FOR THE EFFICIENT FUNCTIONING OF MARSHALLING YARDS

- Shunting operations should not disturb the regular trains
- Should be kept parallel to the running trains
- Movement of wagons in one direction only
- Repair facilities should be provided on one or more sidings
- Connected to all important railway stations
- Goods yard should be nearer to the marshalling yard

TYPES OF MARSHALLING YARDS:

- (i)Flat yard (ii)Gravity yard (iii)Hump yard

FLAT YARD:

- Flat yards are constructed on flat ground, or on a gentle slope. Freight vehicles are pushed by a locomotive and coast to their required location.
- A **flat yard** has no hump, and relies on locomotives for all car movements

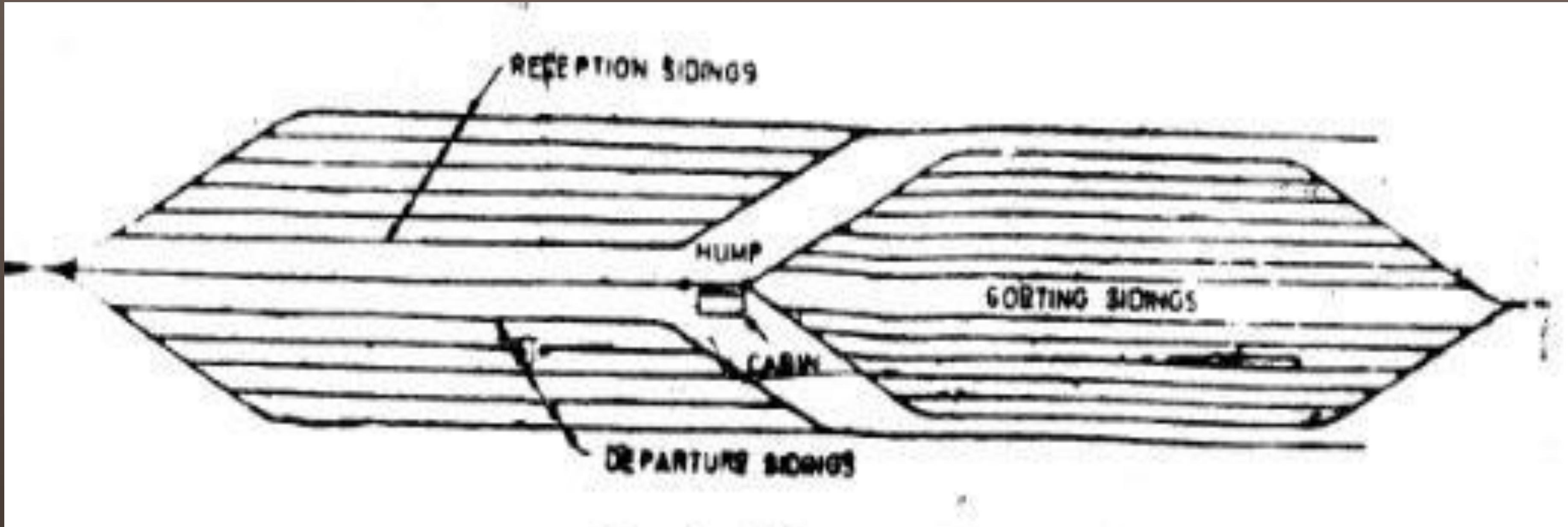
GRAVITY YARD:

- The whole yard is set up on a continuous falling gradient and there is less use of shunting engines.
- Typical locations of gravity yards are places where it was difficult to build a hump yard due to the topography
- Gravity yards also have a very large capacity but they need more staff than hump yards and thus they are the most uneconomical classification yards.

HUMP-YARD:

- These are the largest and most effective classification yards, with the largest shunting capacity—often several thousand cars a day.
- The heart of these yards is the hump: a lead track on a hill (hump) that an engine pushes the cars over.
- Single cars, or some coupled cars in a block, are uncoupled just before or at the crest of the hump, and roll by gravity onto their destination tracks
- A **hump yard** has a constructed hill, over which freight cars are shoved by yard locomotives, and then gravity is used to propel the cars to various sorting tracks

HUMP-YARD:

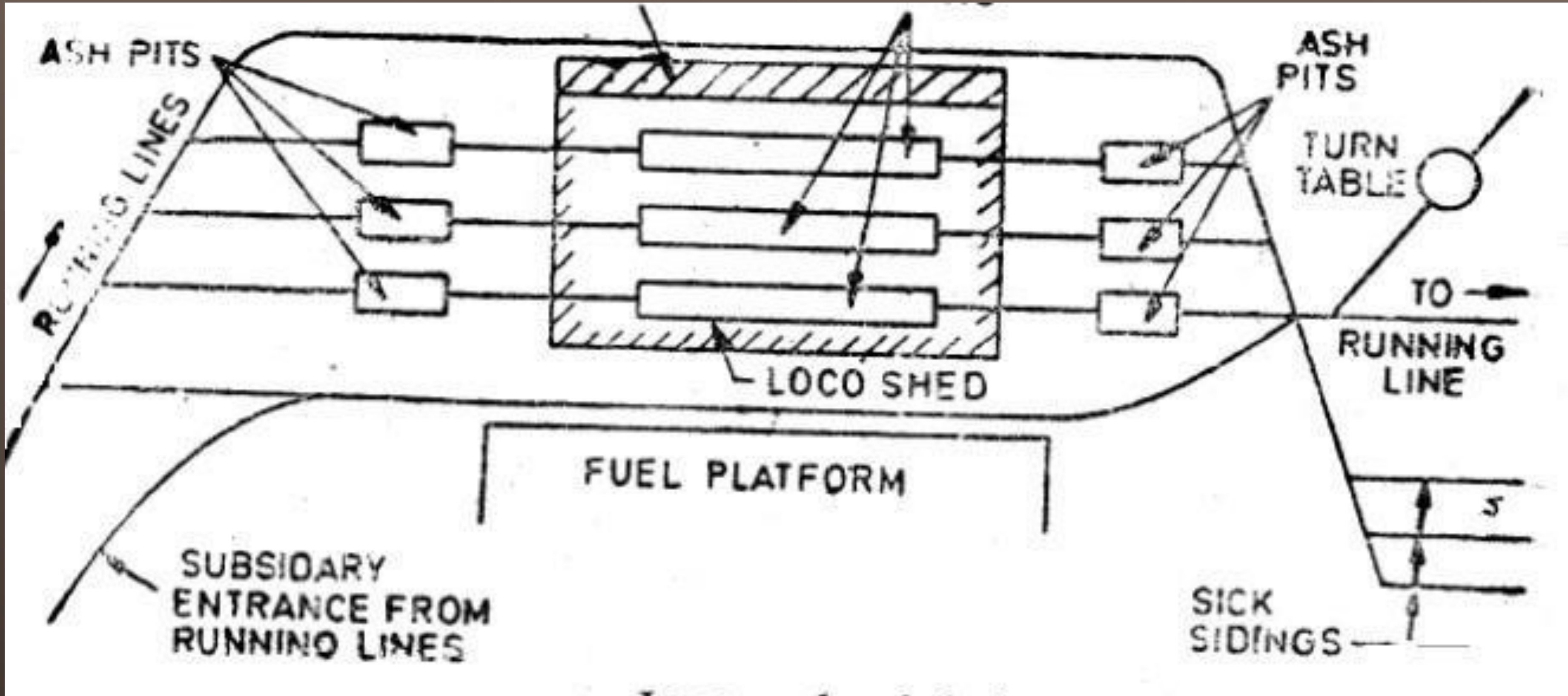


Marshalling yard (Hump type).

LOCOMOTIVE YARDS:

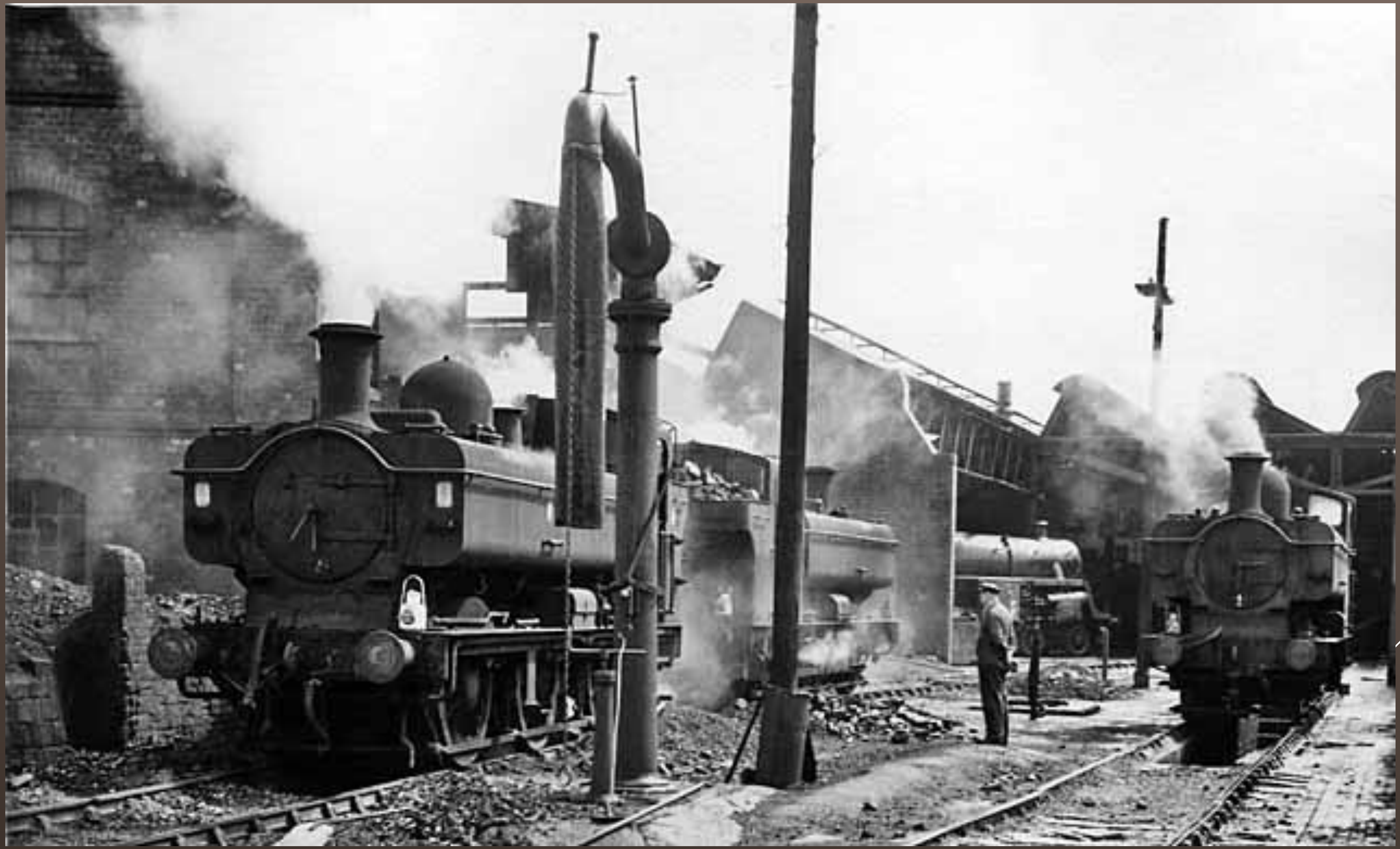
- This is the yard which houses the locomotives for various facilities such as watering, fueling, cleaning, repairing, servicing etc.

LOCOMOTIVE YARDS:



Loco-yard and shed.

LOCOMOTIVE YARDS:



REQUIREMENTS OF A LOCOMOTIVE YARD

- Should be located near the passenger and goods yards
- Water column
- Engine shed, Ash pit, inspection pit, repair shed, turn table
- Hydraulic jack for lifting operations
- Over head tank and loco well
- Sick siding
- Place for future expansion

URBAN TRANSPORT

- **Motorbuses:** This is the most convenient form of transport and is used extensively in metropolitan cities. These buses run mostly on diesel oil and their exhaust emissions have an adverse effect on the environment. Moreover, these buses, though very convenient for transporting passengers, have very limited seating capacity.

- **Trolley Buses:** These are buses that derive their energy through overhead electric transmission. Trolley buses are superior to motorbuses as they do not pollute the environment. On the other hand, huge expenses are incurred in providing overhead traction for supplying power to these buses.

- **Tramways:** Tramways require a track on which the trams can run and as such require the infrastructure of a proper railway track. Their initial cost is quite high. They cause minimal air pollution; however, they contribute significantly to noise pollution. Tramways are almost obsolete now and are used only in some parts of the country such as in Kolkata.

- **Surface Railways:** Surface railways are the cheapest and most extensively used form of railway service in the world. In such a system, the track is laid on a ground that has a suitable embankment or cutting, depending upon the topography of the area.

- **Underground Railways:** In such a system, the railway line is constructed below the ground level. The requisite construction work is done mostly by the ‘cut and cover method’. The area is excavated in the shape of trenches and once the formation is ready, the track is laid, the necessary overhead structures are provided, and finally the trenches are covered and the ground is restored to its original state.

- **Elevated Railways:** This type of railway is provided at an elevation above the ground level. The track is laid on a deck, which is supported by steel or RCC columns. The platforms and even the station building are provided at an elevation for the convenience of passengers. The main advantage of elevated railways is that they do not require any separate land. There is no interference with road traffic as roads can be provided between the columns.

- **Monorail:** The monorail is a form of elevated railway that is provided with only one rail on which trains run. The trains can be suspended on the monorail as in Montreal, Canada, or can be mounted on pylons as in Tokyo, Japan. The monorail system is recommended only in exceptional cases where operating the conventional systems is difficult.

- **Tube Railways:** In this rail system, the underground railways are generally provided at a depth of more than 25 m. The railway line is constructed in a tunnel that is circular or tubular. The main reason for taking the railway so deep into the ground is to avoid it interfering with the water supply mains, sewerage system, telephone lines, gas lines, etc., which are normally located within 10 m of the natural ground.

SUBURBAN RAILWAYS IN METRO CITIES

- The term 'metropolitan city' is commonly used for major or important cities. Most metropolitan cities in India have grown in an unplanned and haphazard manner. Even in places where city master plans were available, the actual lands barely resemble what was envisaged in the plans. Delhi is one such example. The rapid growth in the population and economy of metropolitan cities has resulted in several social and economic problems. The imbalance in the distribution of population and economic activity in these cities has led to large-scale intercity movement resulting in a serious transportation problem.

Advantages

- The Metro Rail System has proven to be most efficient in terms of energy consumption, space occupancy and numbers transported.
- High-capacity carriers – very high volumes of peak hour peak direction trips.
- Eco-friendly – causes no air pollution, much less sound pollution.
- Low energy consumption – 20% per passenger km in comparison to road-based systems.
- Greater traffic capacity – carries as much traffic as 7 lanes of bus traffic or 24 lanes of car traffic (either way).
- Very low ground space occupation – 2 meter width only for elevated rail.
- Faster – reduces journey time by 50% to 75%.

UNDERGROUND RAILWAYS

Advantages

- Trains can run fast and unobstructed in an underground railway system as there are no road crossings or other similar problems.
- As the trains move at incredible speeds, underground railways can deal with a very high concentration of human traffic.
- There is no wastage of land and a large area of the city, which would have otherwise been used for surface railways, remains available for other utilities.
- Provides safety from aerial attacks, particularly during war.

Limitations

- The underground railway system is a very costly arrangement and a heavy financial backing is required. The cost may vary anywhere from Rs 30 million to 100 million per km, depending upon the geographical features and other conditions.
- Special attention needs to be given to the drainage as well as proper ventilation of underground railways.
- During construction, the residents of the city are greatly inconvenienced as excavation work is normally carried out throughout the city. The water supply, electricity supply, and sewerage system of the city are also affected, as the diversion of many of these services is required during the constructional phase.

THANK YOU!!!

|| JAI SRI GURUDEV ||

BGSIT

DEPARTMENT OF CIVIL ENGINEERING

Railways, Harbour, Tunneling & Airports

Module 3

HARBOUR & TUNNELING

INTRODUCTION

- Tunnels are underground or underwater passageway, excavated through the surrounding soil/earth/rock enclosed except for entry and exit, commonly at each end.
- A tunnel may be used for foot or vehicular road traffic, rail traffic, or for a canal.
- Secret tunnels are constructed for military purpose.
- Special tunnels, such as wildlife crossings, are built to allow wildlife to cross human made barriers safely.

WHY TUNNELS ARE CONSTRUCTED

- To provide the shortest route through an obstacle.
- To provide the rapid or timely provision of facilities.
- To reduce the steep gradients especially while climbing up and then climbing down rapidly i.e. in short distance.
- To avoid the expensive acquisition of valuable commercial land.
- To avoid the damage of built urban facilities, roads, pavements, etc.
- When the depth of ground cutting exceeds 20 m.
- To avoid the expensive maintenance cost in open cut area in sliding lands, sinking or unstable grounds, snow-drifting grounds, ponding, marshy, soaked, etc areas.

HISTORY OF TUNNELS

- The first ever tunnels were made by cavemen.
- About 2180B.C., Babylonia tunnel was built under Euphrates river. It was 900m long, 3600mm wide and 4500mm high.
- The largest tunnel built in ancient times was 1470m long, 7600mm wide and 9000mm high between Naples and Pozzuoli in 36B.C.

TYPES OF TUNNELS

CLASSIFIED BY	EXAMPLE OF TUNNELS
• Purpose	Railway tunnels, metro system, highway tunnels, pedestrian tunnels, water tunnels, sewage tunnels, services tunnels, storage tunnels.
• Geological location / condition	Rock tunnels, earth tunnels, and submerged tunnels.
• Cross-sectional shapes	Rectangular shape, circular shape, elliptical shape, egg shape, horse shoe shape, and segmental shape.

SHAPES OF TUNNEL

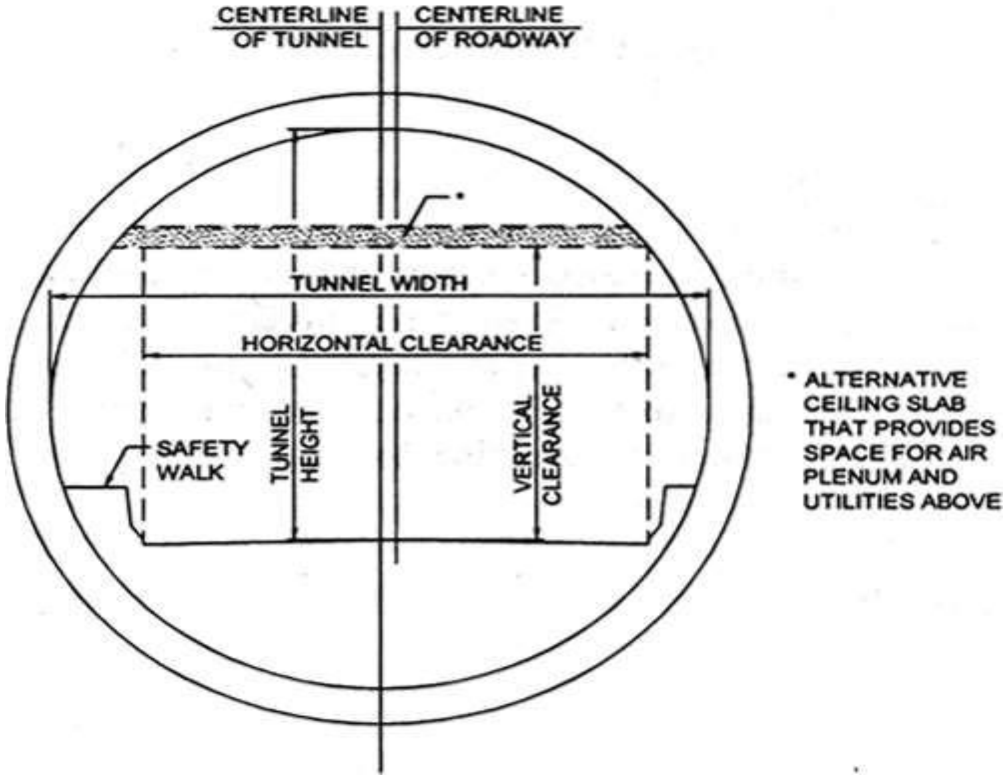
The **shapes of tunnel** are usually determined by their purpose, ground conditions, construction method and/or lining materials.

There are four shapes of tunnel:-

- Circular shape tunnel
- Elliptical shape tunnel
- Horseshoe shape tunnel
- Oval/Egg shape tunnel

CIRCULAR SHAPE TUNNEL

- This type of section offers greater resistance to external pressure.
- If ground is highly unstable, such as soft clay or sand, it is necessary to use circular section.
- For carrying water and sewerage circular shape tunnels are used e.g. Aqueduct



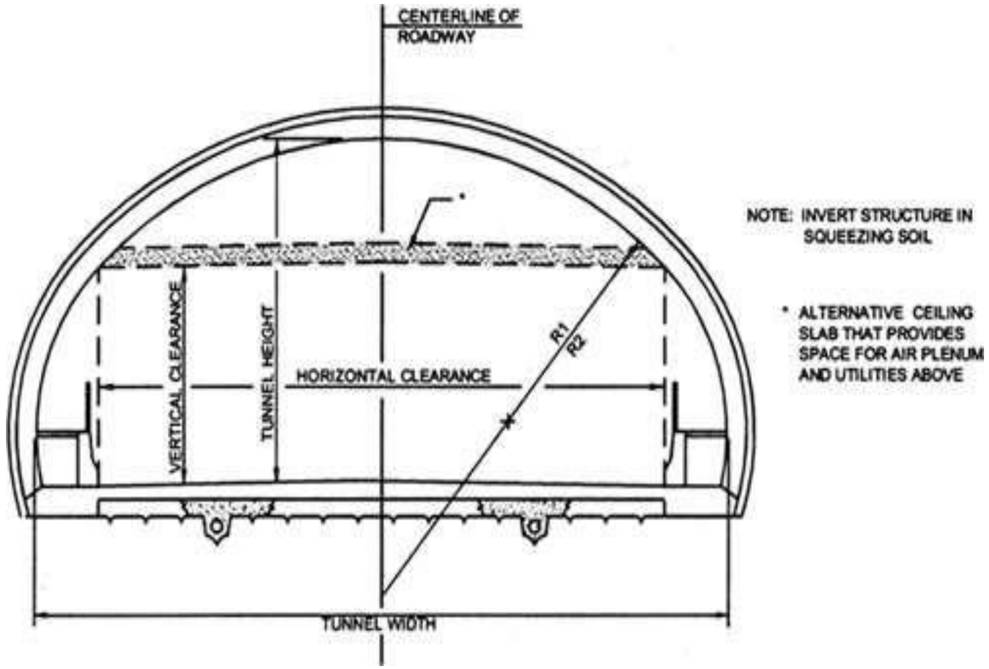
CIRCULAR TUNNEL

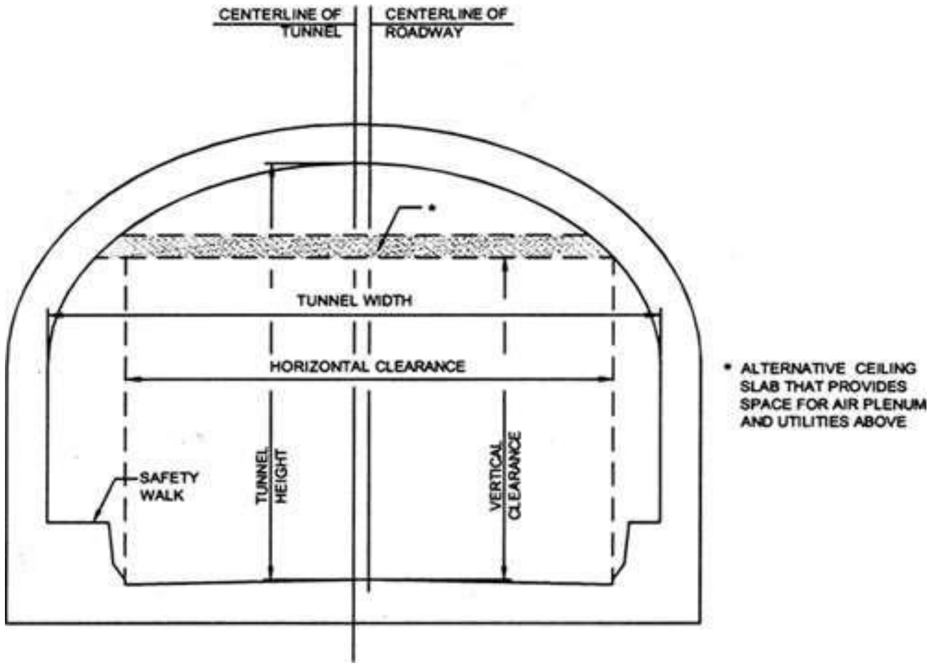
ELIPTICAL SHAPE TUNNEL

- They are used in grounds compare to rock.
- These tunnel serve as water sewage condition.
- The smaller cross section at the bottom maintains the flow at the required self cleaning velocity.
- Because of their narrow base they are not used as traffic tunnels.

OVAL/EGG SHAPE TUNNEL

- These section have narrow cross-sections at bottom. They are best suited for carrying sewage.
- They maintain self-cleansing velocity of flow of sewage both in dry and rainy seasons.
- They resist external as well as internal pressure due to their circular walls.
- These section of tunnels are difficult to construct





HORSESHOE SHAPE TUNNEL

- They are commonly used for rock tunnelling.
- These shape consist of horizontal roof together with arched sides and a curved invert.
- It has the advantage of utilising the compressive strength of concrete in resisting the loading by means of arch action and the base is wide enough for traffic.
- They are most popular as traffic tunnels for road and railway routes.
- They are also difficult to construct.

FACTORS AFFECTING SELECTION OF TUNNELING METHOD

- Geological and Hydrological condition
- Cross-section and length of continuous tunnel
- Local experience and Time/Cost consideration
- Shape of tunnel
- Managing the risk of variations in ground quality
- Limits of surface disturbance

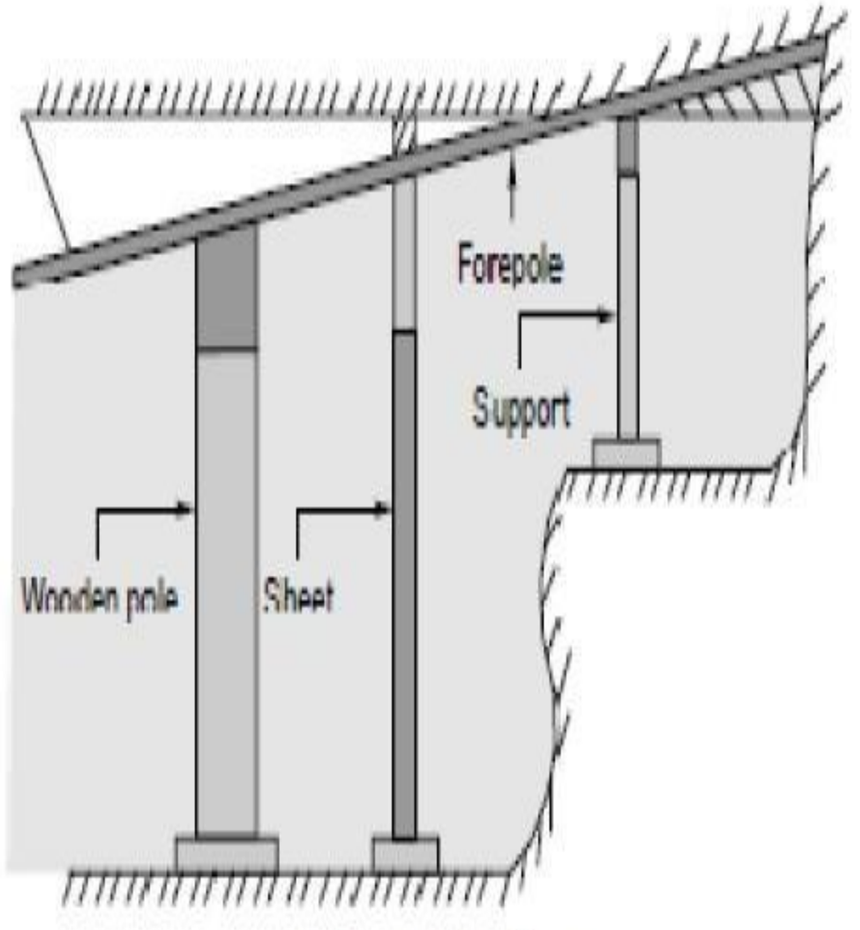
Tunneling in Soft Ground or Soft Rock

- Tunneling in soft ground or soft rock is a specialized job.
- It does not involve the use of explosives and the requisite excavation work is done using hard tools such as pickaxes and shovels.
- In recent times, compressed air has also been used for this purpose.
- During excavation, the rail requires support at the sidewalls and the roofs depending upon the type of soil. The support could be provided in the form of timber or steel plates or other similar material.
- The various operations involved in soft rock tunneling are as follows.
  - ✓ Excavation or mining
  - ✓ Removal of excavated material
  - ✓ Scaffolding and shuttering
  - ✓ Lining of tunnel surface
- The nature of the ground is the most important factor in deciding the method to be used for tunneling.

Forepoling method

Forepoling is an old method of tunneling through soft ground. In this method, a frame is prepared in the shape of the letter A, placed near the face of the tunnel, and covered with suitable planks. Poles are then inserted at the top of the frame up to a viable depth. The excavation is carried out below these poles, which are supported by vertical posts. The excavation is carried out on the sides and the excavated portion is suitably supported by timber. The entire section of the tunnel is covered thus. The process is repeated as the work progresses.

Forepoling is a slow and tedious process and requires skilled manpower and strict supervision. The method has to be meticulously repeated in sequence and there is no short cut for the same

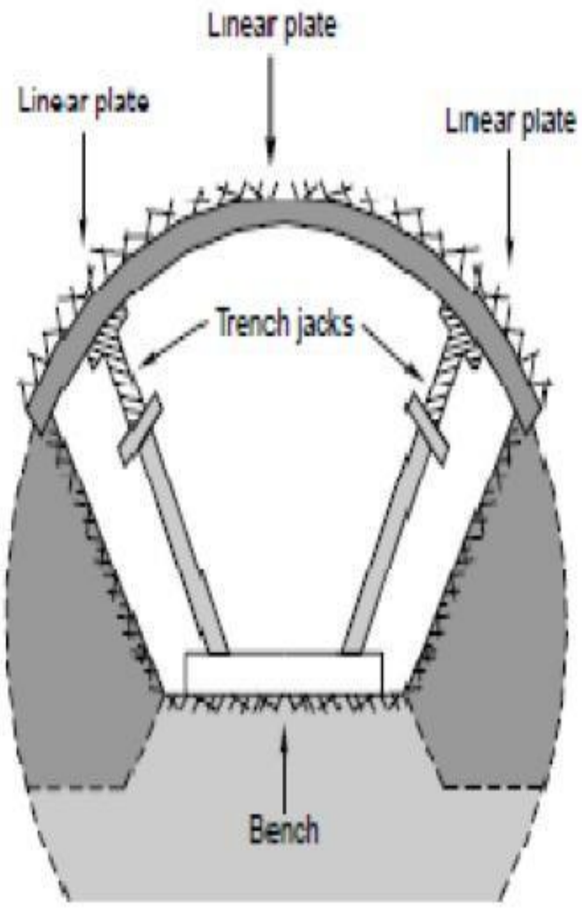


Cross-sectional view

Linear Plate Method

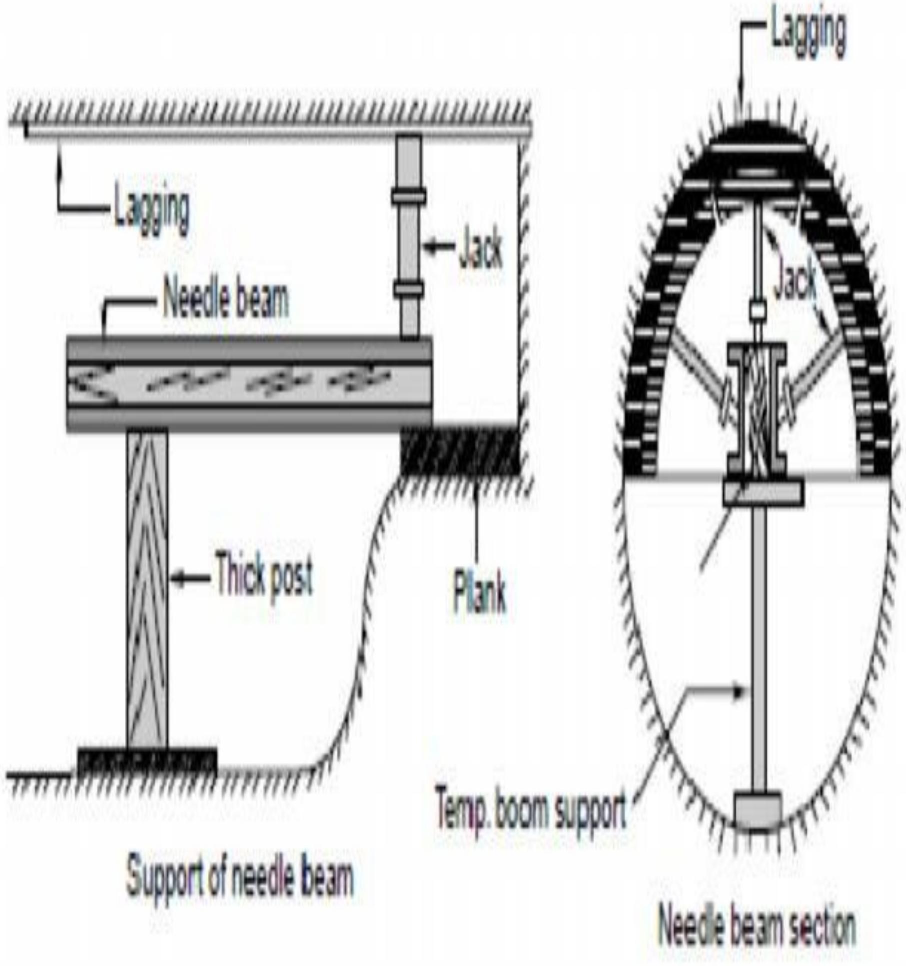
In the linear plate method, timber is replaced by standard size pressed steel plates. The use of pressed steel plates is a recent development. The method has the following advantages.

- ➢ The linear plates are light and can be handled easily.
- ➢ The number of joints is less, as the linear plates are bigger in size, and as such the maintenance cost is low.
  - ✓ The steel plates are fireproof and can be safely used while working in compressed air condition.
  - ✓ The necessary work can be done by semi-skilled staff.
  - ✓ There is considerable saving in terms of the excavation and concrete required.



Needle Beam Method

The needle beam method is adopted in terrains where the soil permits the roof of the tunnel section to stand without support for a few minutes. In this method, a small drift is prepared for inserting a needle beam consisting of two rail steel (RS) joists or I sections and is bolted together with a wooden block in the centre. The roof is supported on laggings carried on the wooden beam. The needle beam is placed horizontally with its front end supported on the drift and the rear end supported on a vertical post resting on the lining of the tunnel. Jacks are fixed on the needle beam and the tunnel section is excavated by suitably incorporating timber. This method of tunnelling is more economical compared to other methods.



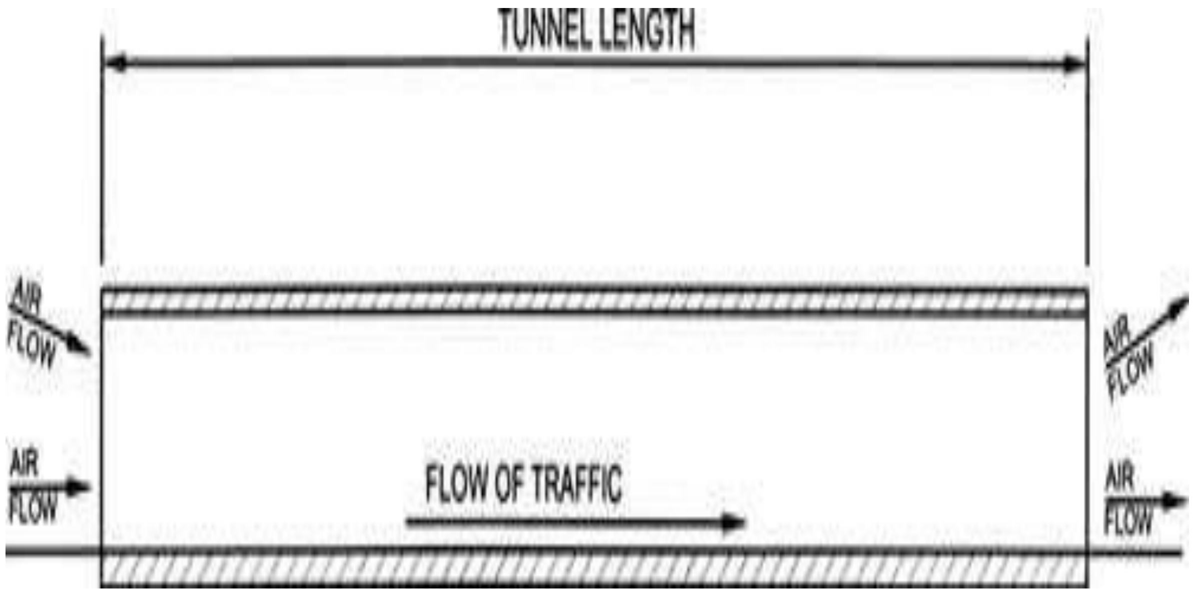
TUNNEL VENTILATION SYSTEM

A tunnel should be properly ventilated during as well as after the construction for the reasons given below.

- To provide fresh air to the workers during construction.
- To remove the dust created by drilling, blasting, and other tunnelling operations.
- To remove dynamite fumes and other objectionable gases produced by the use of dynamites and explosives.
- The methods listed below are normally adopted for the ventilation of a tunnel

NATURAL VENTILATION

- A naturally ventilated tunnel is as simple as the name implies. The movement of air is controlled by meteorological conditions and the piston effect created by moving traffic pushing the stale air through the tunnel.
- This effect is minimized when bi-directional traffic is present.
- The meteorological conditions include elevation and temperature differences between the two portals, and wind blowing into the tunnel.
- Another configuration would be to add a centre shaft that allows for one more portal by which air can enter or exit the tunnel.
- Many naturally ventilated tunnels over 180 m (600 ft) in length have mechanical fans installed for use during a fire emergency.



Mechanical ventilation by blow-in method In the blow-in method, fresh air is forced through a pipe or fabric duct by the means of a fan and supplied near the washing face (or the drilling face; the drilling operation requires the washing of bore holes too). This method has the advantage that a fresh air supply is guaranteed where it is required the most. The disadvantage is that the foul air and fumes have to travel a long distance before they can exit the tunnel and in the process it is possible that the incoming fresh air will absorb some dust and smoke particles.

Mechanical ventilation by exhaust method In the exhaust or blow-out method, foul air and fumes are pulled out through a pipe and is expelled by a fan. This sets up an air current that facilitates the entrance of fresh air into the tunnel. This method has the advantage that foul air is kept out of the washing face. The disadvantage, however, is that fresh air has to travel a long distance before it can reach the washing face during which period it may absorb some heat and moisture.

Combination of blow-in and blow-out methods By combining the blow-in and blow-out methods using a blower and an exhaust system, respectively, a tunnel can be provided with the best ventilation. After blasting the ground, the exhaust system is used to remove the smoke and dust. After some time, fresh air is blown in through the ducts and the rotation of the fans is reversed to reverse the flow of air.

ADVANTAGES

- Tunnels are more economical than open cuts beyond certain depths.
- Tunnels avoid disturbing or interfering with surface life and traffic during construction.
- Tunnels prove to be cheaper than bridges or open cuts to carry public utility services like water, sewer and gas.
- If tunnels are provided with easy gradients, the cost of hauling is decreased.
- In case of aerial warfare and bombing of cities, the tunnels would grant better protection as compared to bridges.

Drainage of Tunnels

- Good drainage of the tunnels is very essential in order for them to operate safely and smoothly during the construction period as well as afterwards.
- The sources of water for this purpose include ground water and water collected from the washing of bore holes.
- Water seeping in up through the ground as well as from the washing of bore holes is collected in sump wells and pumped out.
- If the tunnel is long, a number of sump wells are provided for the collection of water.
- After the construction is over, drainage ditches are provided along the length of the portion of the tunnel that slop from the portal towards the sump well and are used for pumping the water out.

Sumps & pumps: The sumps connected by a pipe line are provided at a distance of about 300 m & water is pumped from one sump to another until it is thrown out of tunnel opening

Grouting: The above method cannot be used, if water is percolating from the top of the tunnel. In such cases, the grouting is adopted to make the seams water-tight.

Pilot tunnel: In cases where pilot tunnel at a lower level than the main tunnel is constructed parallel to it for drainage of water

TUNNEL LINING MATERIALS

- Linings are required in most tunnels, always in soft ground and frequently in rock.
- They are required for two purposes: structurally to retain the earth and water pressure, and operationally to provide an internal surface appropriate to the function of the tunnel.
- The principal materials for permanent lining of bored tunnels are:
  1. Brickwork, blockwork and masonry
  2. Insitu concrete
  3. Preformed segments
  4. Sprayed Concrete

DESIGN CONSIDERATIONS

- Water
- Constructability
- Tunnel usage

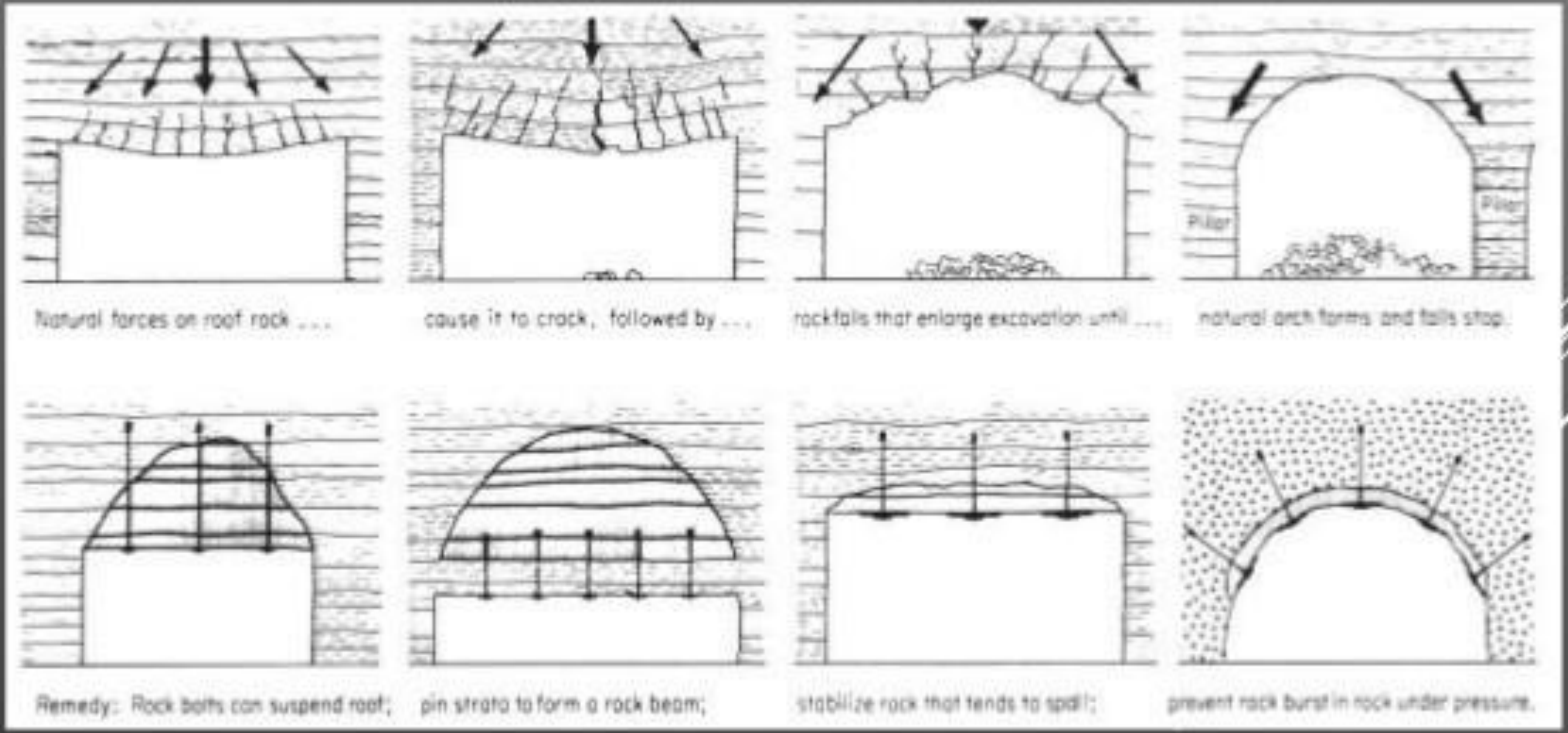
COMMON TYPES OF LINING USED IN TUNNELS

1. Natural support in rock

   When the tunnel is being bored through good quality rock

2. ROCK REINFORCEMENT

- Steel bolts are frequently set in holes drilled into the rock to assist in supporting the entire roof or individual rock slabs that tend to fall into a tunnel



3. SHOTCRETE

- Pneumatically applied mortar and concrete are increasingly being used for the support of underground excavations

4. WIRE MESH:-

- Wire mesh is used to support small pieces of loose rock or as reinforcement for shot crete.
- Two types of wire mesh are commonly used in underground excavations:
- 1**. Chain-link mesh**:- commonly used for fencing
- 2. **Weld mesh**:- commonly used for reinforcing shotcrete.

5. IN SITU CONCRETING

- The process of placing concrete in situ was incompatible with timber supports.
- The first uses of concrete were for tunnels in good rock and it was only with the introduction of steel supports that concrete became the norm for a tunnel lining material.
- In-situ forms used for lining tunnels are, with few exceptions, of the travelling type, constructed of steel.

THANK YOU

☺

AIR TRANSPORT

Module 4 &5

Airport History

- The world's first airport was built in 1928 at Croydon near London (England). It was the main airport for London till it was closed down in 1959, after the World War II. It is now open as a visitor centre for aviation.

2015 statistics

Rank	Airport	Location
1.	Hartsfield–Jackson Atlanta International Airport	Atlanta, Georgia
2.	Beijing Capital International Airport	Chaoyang-Shunyi, Beijing
3.	Dubai International Airport	Garhoud, Dubai
4.	O'Hare International Airport	Chicago, Illinois

Hong Kong International Airport – Chek Lap Kok, Hong Kong


Incheon International Airport

Air transport has the following characteristics:

1. Unbroken Journey: Air transport provides unbroken journey over land and sea. It is the fastest and quickest means of transport.
2. Rapidity: Air transport had the highest speed among all the modes of transport.
3. Expensive: Air transport is the most expensive means of transport. There is huge investment in purchasing aero planes and constructing of aerodromes.
4. Special Preparations: Air transport requires special preparations like wheelers links, meteorological stations, flood lights, searchlights etc.

Fastest Mode of Transport:

Advantages:

1. High Speed: The supreme advantage of air transport is its high speed. It is the fastest mode of transport and thus it is the most suitable mean where time is an important factor.
2. Comfortable and Quick Services: It provides a regular, comfortable, efficient and quick service.
3. No Investment in Construction of Track: It does not require huge capital investment in the construction and maintenance of surface track.
4. No Physical Barriers: It follows the shortest and direct route as seas, mountains or forests do not come in the way of air transport.
5. Easy Access: Air transport can be used to carry goods and people to the areas which are not accessible by other means of transport.

6. Emergency Services: It can operate even when all other means of transport cannot be operated due to the floods or other natural calamities. Thus, at that time, it is the only mode of transport which can be employed to do the relief work and provide the essential commodities of life.

7.Quick Clearance: In air transport, custom formalities can be very quickly complied with and thus it avoids delay in obtaining clearance.

8.Most Suitable for Carrying Light Goods of High Value: It is most suitable for carrying goods of perishable nature which require quick delivery and light goods of high value such as diamonds, bullion etc. over long distances.

9.National Defence: Air transport plays a very important role in the defence of a country. Modern wars have been fought mainly by airplanes. It has upper hand in destroying the enemy in a very short period of time. It also supports over wings of defence of a country.

10Space Exploration: Air transport has helped the world in the exploration of space.

Disadvantages:

In spite of many advantages, air transport has the following limitations:

1.Very Costly: It is the costliest means of transport. The fares of air transport are so high that it is beyond the reach of the common man.

2.Small Carrying Capacity: Its carrying capacity is very small and hence it is not suitable to carry cheap and bulky goods.

3.Uncertain and Unreliable: Air transport is uncertain and unreliable as it is controlled to a great extent by weather conditions. Unfavorable weather such as fog, snow or heavy rain etc. may cause cancellation of scheduled flights and suspension of air service.

4.Breakdowns and Accidents: The chances of breakdowns and accidents are high as compared to other modes of transport. Hence, it involves comparatively greater risk.

5. Large Investment: It requires a large amount of capital investment in the construction and maintenance of aeroplanes. Further, very trained and skilled persons are required for operating air service.

6.Specialised Skill: Air transport requires a specialized skill and high degree of training for its operation.

7.Unsuitable for Cheap and Bulky Goods: Air transport is unsuitable for carrying cheap, bulky and heavy goods because of its limited capacity and high cost.

8.Legal Restrictions: There are many legal restrictions imposed by various countries in the interest of their own national unity and peace.

Airport Layout

Some Basic Definitions:

1. **Aircraft: "Any machine which finds its support in the atmosphere due to reactions of the air is defined as an Aircraft".**

   It is a general term which includes aero-plane, helicopter, rocket, etc. It may be lighter or heavier than air.

   a) subsonic aircraft- Aircraft speed is less than the speed of sound

   b) supersonic aircraft- Aircraft speed is greater than the speed of sound.

2. **Aerodrome:** Any defined area on land or water intended to be used for the arrival and departure of an aircraft is called aerodrome.

3. **Airport:** It is an aerodrome which is principally intended for the use of commercial services. It is provided with custom facilities. If it service any international traffic. i.e if it is designed as an international airport. When an airport does not serve international traffic, it is known as non-international or domestic airport.
4. **Airfield:** it is an area which is used for landing and take-off of an aircraft.

5) **Landing area:** An airport consists of landing area and terminal area. Landing area is used for landing & take-off of an aircraft.

1) Runway
2) Taxiway

6) **Terminal area:** It includes the following

a) Terminal building
b) Aircraft apron
c) Gate position
d) Hangars (Shelters)
e) Automobile parking area

7) **Runway:** It is paved long & narrow rectangular strip which is actually used for landing & take-off of aero-planes.

8) **Taxiway:** It is a paved way over which an aero-plane may taxi while going to & from runway and loading apron. Taxiways also connect two neighboring runway, runway with a service and maintenance hangar.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18
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Components of An Airport Layout

1. Runway
2. Terminal Building
3. Apron
4. Taxiway
5. Aircraft Stand
6. Hanger
7. Control Tower
8. Parking

1. Runways

A runway is the area where an aircraft lands or takes off. It can be grass, or packed dirt, or a hard surface such as asphalt or concrete. Runways have special markings on them to help a pilot in the air to tell that it is a runway (and not a road) and to help them when they are landing or taking off. Runway markings are white.


36


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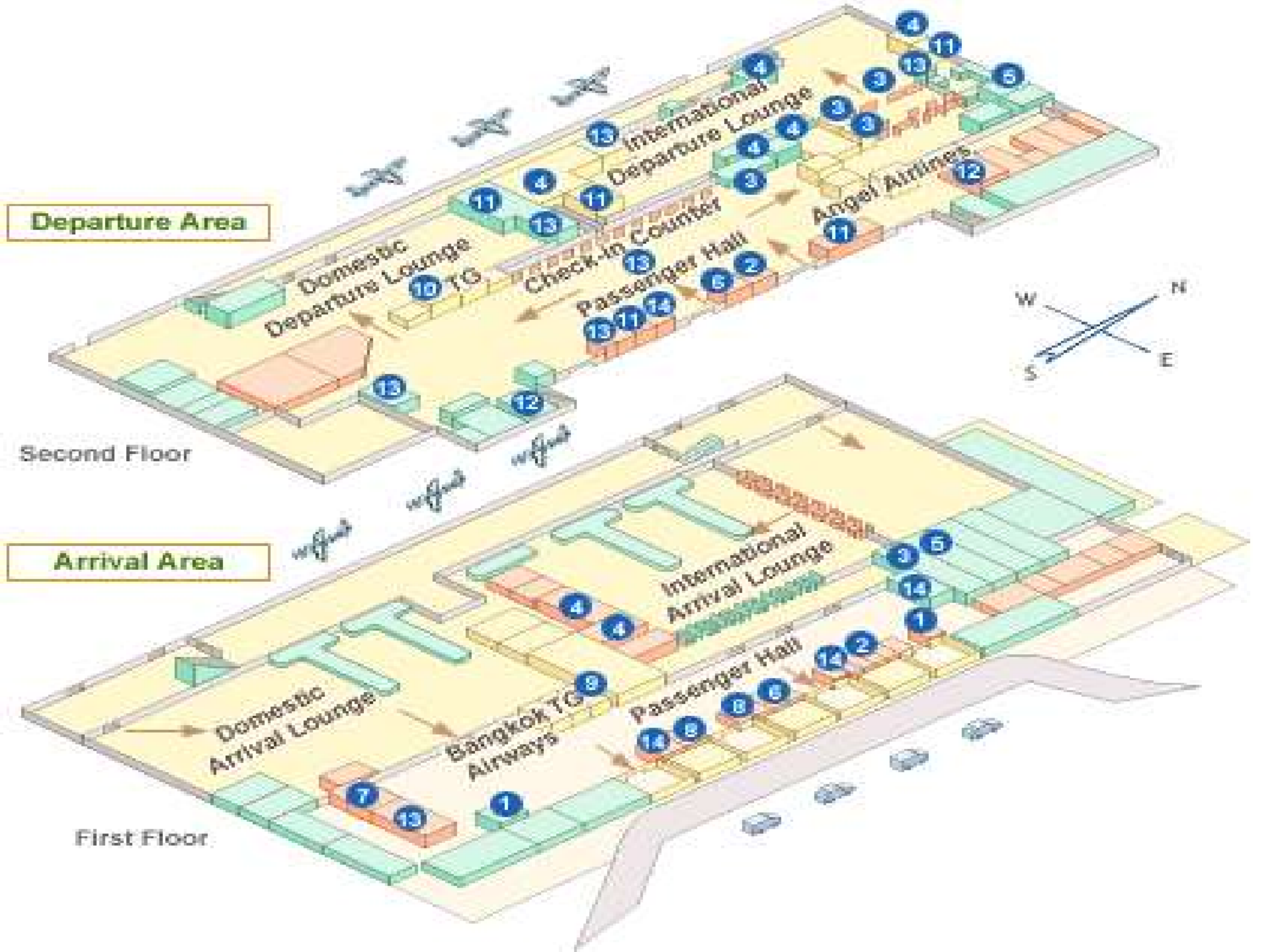
2. Terminal Buildings

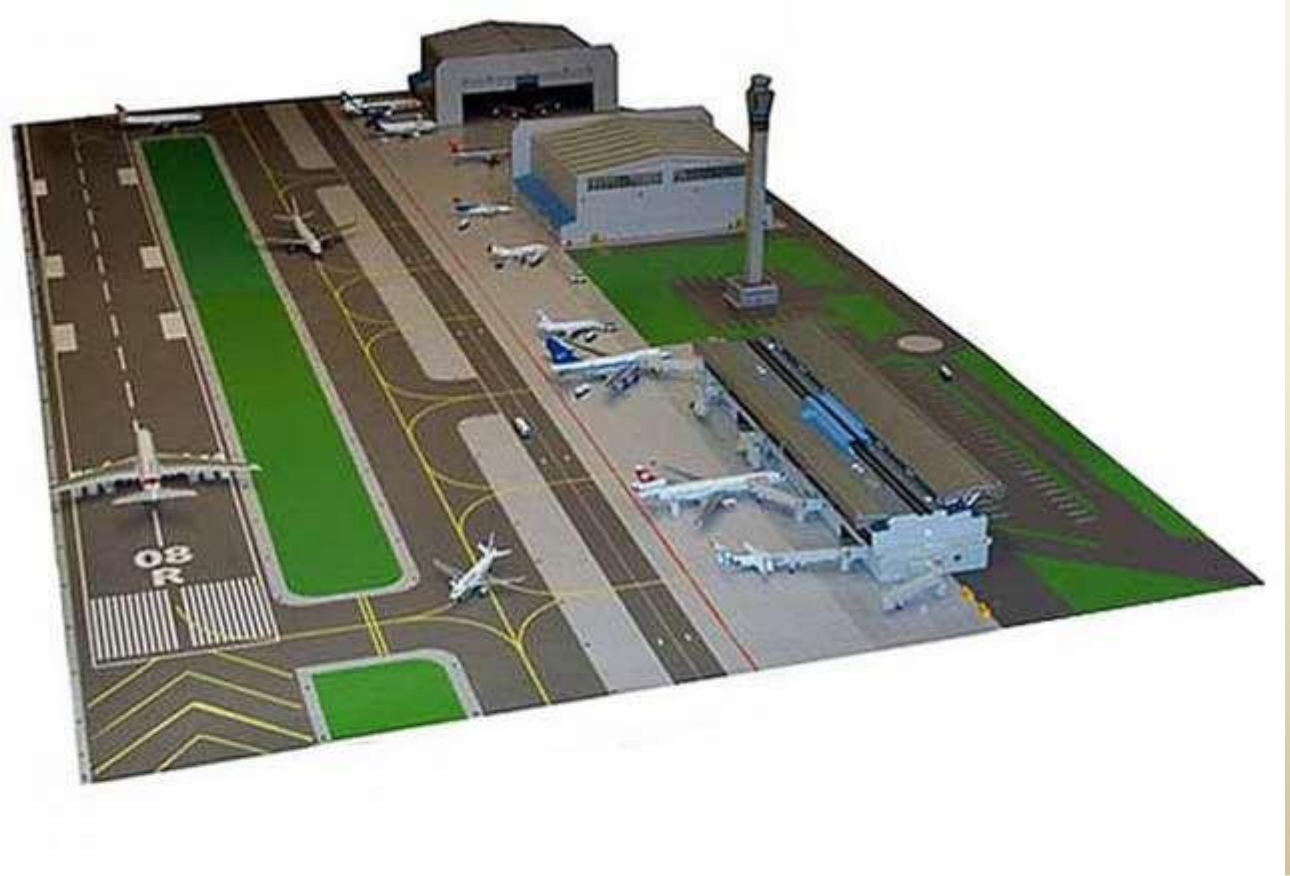
Also known as airport terminal, these buildings are the spaces where passengers board or alight from flights. These buildings house all the necessary facilities for passengers to check-in their luggage, clear the customs and have lounges to wait before disembarking. The terminals can house **cafes**, lounges and **bars** to serve as waiting areas for passengers. Ticket counters, luggage check-in or transfer, security checks and customs are the basics of all airport terminals. Large airports can have more than one terminal that are connected to one another through link ways such as walkways, sky-bridges or trams. Smaller airports usually have only one terminal that houses all the required facilities.



Departure Area
Second Floor
International Departure Lounge
Domestic Departure Lounge
TG
Check-in Counter
Passenger Hall
Angel Airlines
W
N
S
E
Arrival Area
International Arrival Lounge
Domestic Arrival Lounge
Bangkok TG
Airways
Passenger Hall
First Floor

3. Aprons

Aircraft aprons are the areas where the aircraft park. Aprons are also sometimes called ramps. They vary in size, from areas that may hold five or ten small planes, to the very large areas that the major airports have. Unlike the runways or taxiways, vehicles can use aprons.



4. Taxiway

A taxiway is a path on an airport connecting runways with ramps, hangars, terminals and other facilities. They mostly have hard surface such as asphalt or concrete, although smaller airports sometimes use gravel or grass.

5. Aircraft Stand

A portion of an apron designated as a taxiway and intended to provide access to aircraft stands only.

5. Aircraft Stand

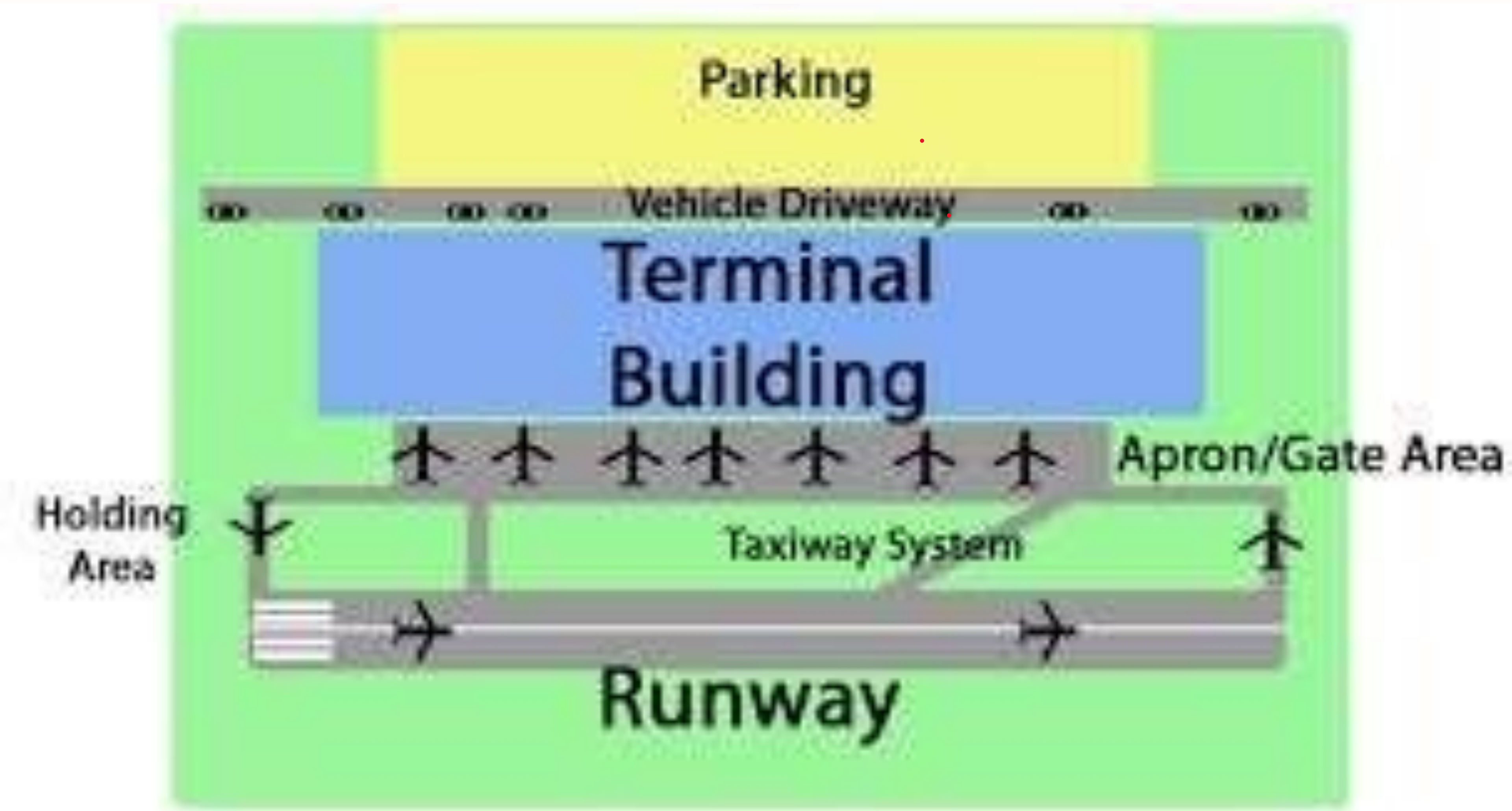
A portion of an apron designated as a taxiway and intended to provide access to aircraft stands only.

7. Control Tower

A tower at an airfield from which air traffic is controlled by radio and observed physically and by radar.

8. Parking

Parking is a specific area of airport at which vehicles park



Parking
Vehicle Driveway
Terminal Building
Apron/Gate Area
Holding Area
Taxiway System
Runway

Airport Site Selection

Factors

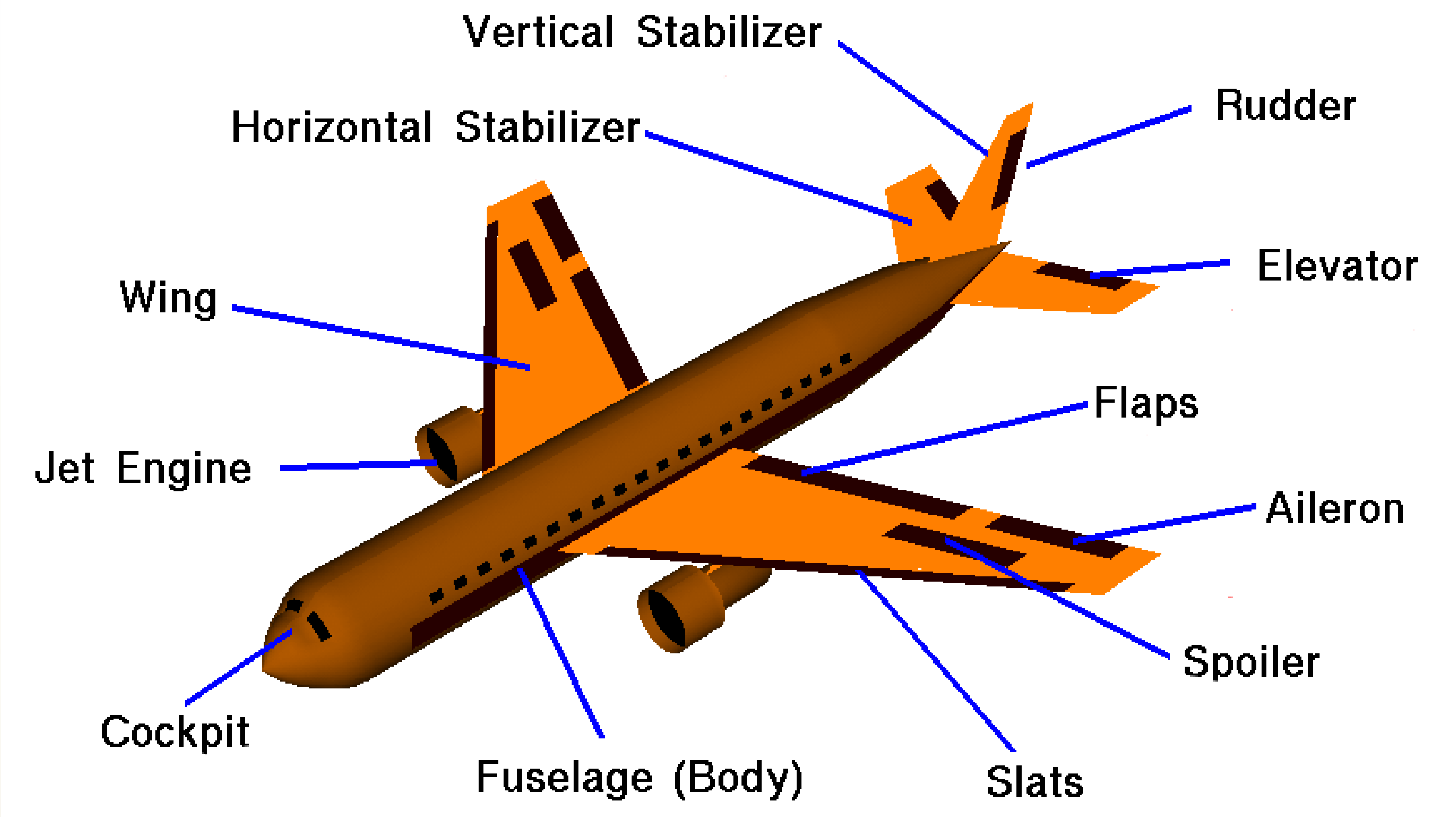
- Regional plan
- Airport use
- Proximity to other airports
- Ground accessibility
- Topography
- Obstructions
- Visibility
- Wind
- Noise Nuisance
- Grading, drainage and soil characteristics
- Future development
- Availability of utilities from town
- Economic considerations

Airport Layout

Aircraft Characteristics

Aircraft characteristics are of prime importance to the airport planning and design. The following characteristics need to be studied.

- Type of Propulsion (piston engine, jet engine and ram engine)
- Size of aircraft
- Minimum turning radius
- Minimum circling radius
- Speed of aircraft
- Capacity of aircraft
- Aircraft weight & wheel configuration
- Jet Blast
- Fuel Spillage


Vertical Stabilizer
Rudder
Horizontal Stabilizer
Elevator
Wing
Flaps
Jet Engine
Aileron
Spoiler
Cockpit
Fuselage (Body)
Slats

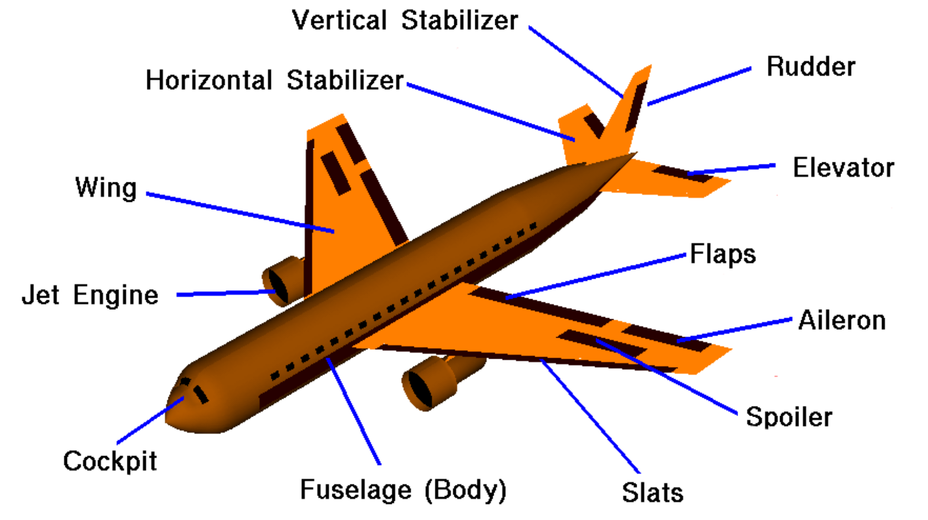
Type of Propulsion:

The size of aircraft, its circling radius, speed characteristics, weight carrying capacity, noise nuisance etc. depend upon the type of propulsion of the aircraft.

the basic runway length also depends on the type of propulsion used in aircraft.

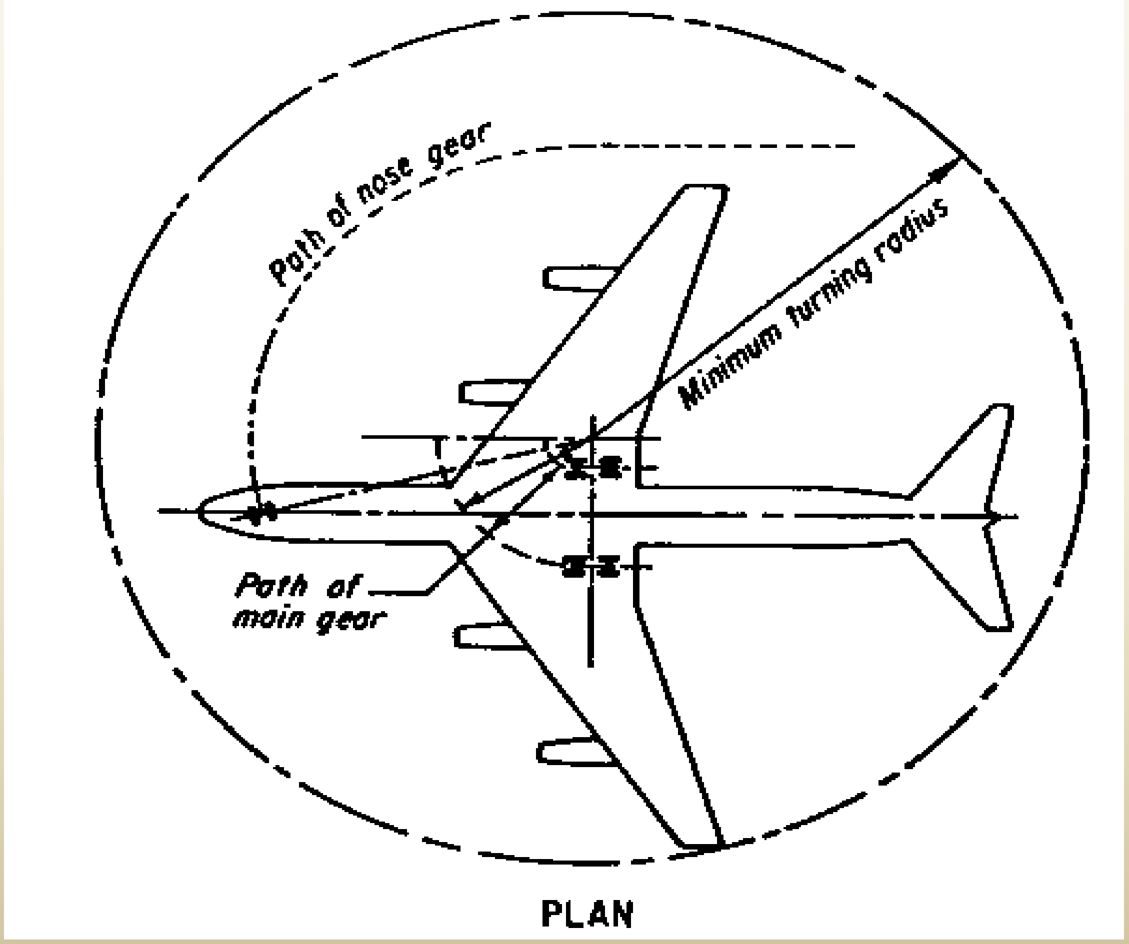
Size of aircraft:

The Size of aircraft involves following important dimensions, (i) wing span (ii) height (iii) distance b/w main gears i.e. gear tread (iv) wheel base & tail width.



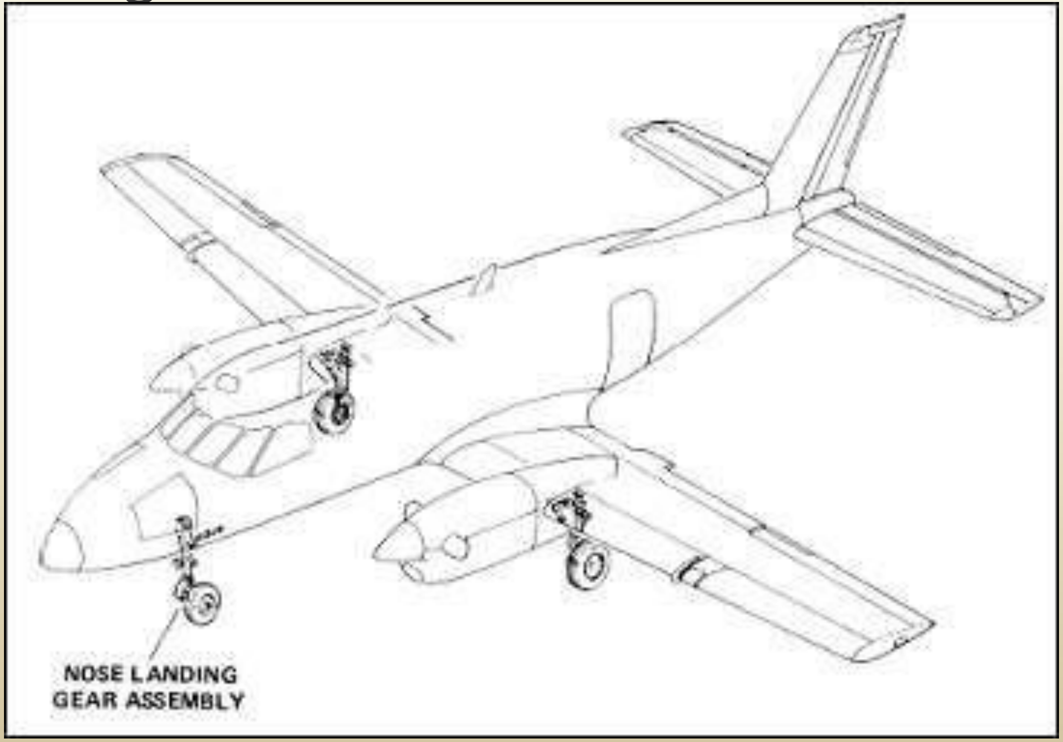
Minimum Turning radius:

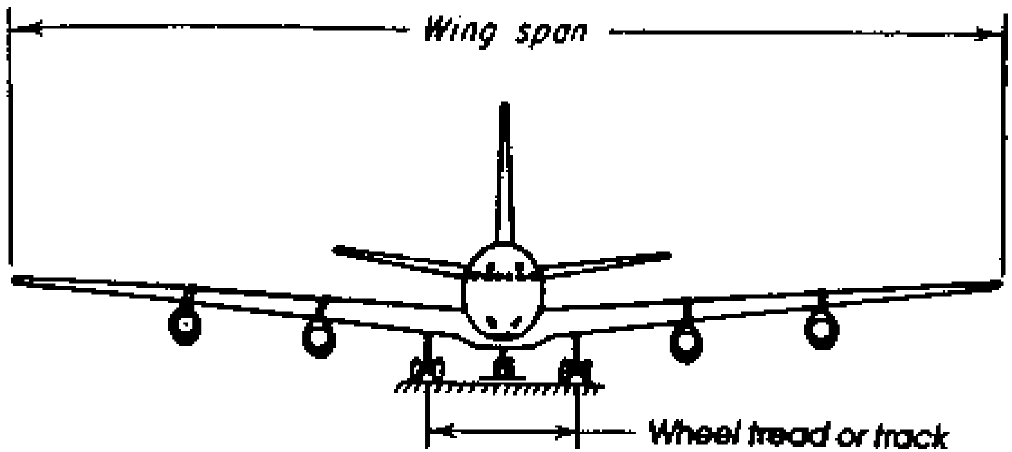
In order to decide the radius of taxiway, its very essential to study the geometry of turning movement of aircraft.



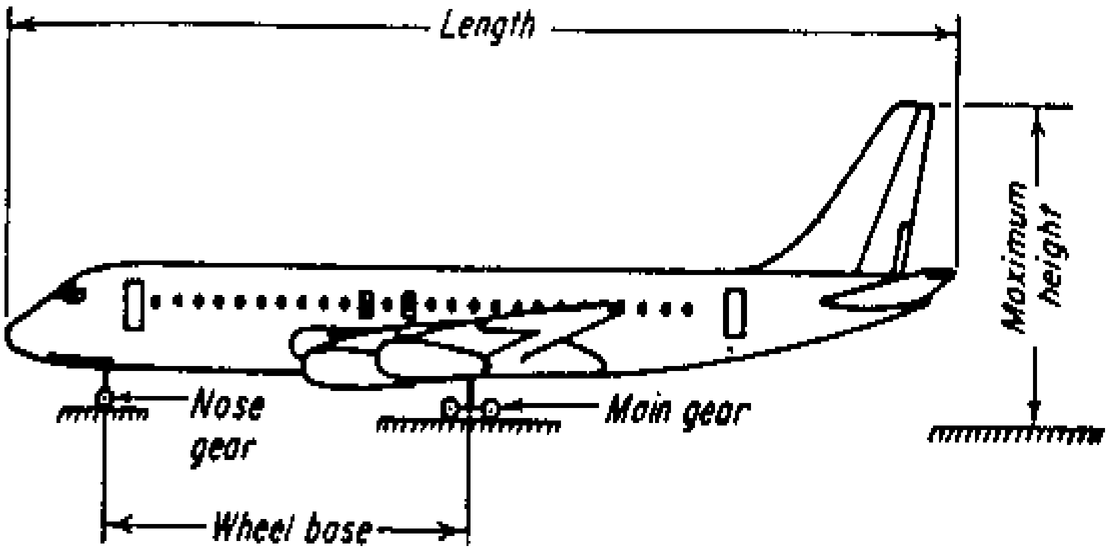
Minimum Turning radius:

- While taking a turn, the nose gear is steered and therefore, makes an angle with the axis of the main gear, called angle of rotation. The point of intersection of main gear and line through axis of steered nose gear is called point of rotation.
- The maximum angle of rotation is 50° - 60°
- The line joining the center of rotation and the tip of the farthest wing of the aircraft is known minimum turning radius





FRONT VIEW



SIDE VIEW

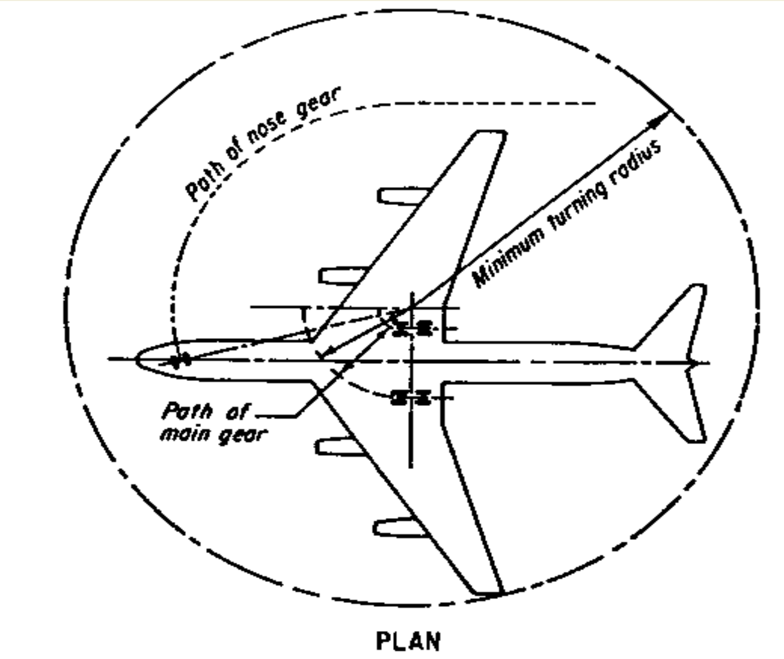
Minimum Circling Radius:

There is certain minimum radius with which the aircraft can take turn in space.

Its radius depends upon the type of aircraft, air traffic volume & weather conditions.

The radii recommended for different types of aircraft are as follows.

- Small general aviation aircraft = 1.6 km
- Bigger aircraft = 3.2 km
- Piston engine aircraft = 13 km
- Jet engine aircraft = 80 km



Speed of Aircrafts:

- The speed of aircraft can be defined in two ways. i.e. Cruising speed or air speed.
- Cruising speed is the speed of aircrafts with respect to the ground, when the aircrafts is flying in air at its maximum speed.
- Air speed is the speed of aircraft relative to the wind.
- If the aircraft is flying at a speed of 500 kmph & there is a head wind of 50 kmph, air speed will be 450 kmph.

Aircraft capacity:

- The number of passengers, baggage & fuel that can be accommodated in the aircrafts depends upon the capacity of aircraft.

Weight of aircraft & wheel configuration:

- Weight of the aircraft directly influence the length of the runway as well as the structural requirements i.e. the thickness of the runway, taxiway, apron & hangars.

Jet Blast:

- This is the blast that comes out of the jet engine at the rear of the aircraft and provides the force movement of the aircraft.
- But, if we consider it in case where the aircraft is standing and the jet blast is coming from the rear, that is so hot and it creates a severe condition for the things on which it will be falling.
- So the severity is going to depend on two things; one is the

  - height of the tail pipe from the round
  - angle of the tail pipe through which this jet blast will be coming out at the tail end.

  So if it is in the upward direction then it will go up if it is in the downward direction it will create a pro effect on the pavement on which the aircraft is standing and therefore there is a need to erect the blast fences which can control the damage to the building or damage to the pavement.

Fuel spillage:

- At loading aprons & shelter it is difficult to avoid spillage completely, but effort should be made to bring it within minimum limit.
- The flexible pavements are seriously affected by the fuel spillage.

Air Transport Agencies

- International Civil Aviation Organization (ICAO)
- Federal Aviation Administration (FAA)
- Airport Authority of India.
- Air India International Corporation.
- Indian Airlines Corporation.
- Private Air Transport Agencies, Jet Airways, Sahara Airways.

✈ Airport Classification

1) Based on Take-off & Landing

- Conventional Take off & Landing Airport
  - Runway length > 1500 m
- Reduced Take-Off & Landing Airport
  - Runway length 1000 to 1500 m
- Short Take-Off & Landing Airport
  - Runway length 500 to 1000 m
- Vertical Take-Off & Landing Airport
  - Operational area 25 to 50 sq.m

2) ICAO Classification: Based on Geometric Design

- The classification has been done by using code letters viz. A to E in which the A type of airport has the longest runway length and E type has the shortest length.

Airport Classification

ICAO Classification: Based on Length of Runway.

Code No	Basic Runway Length (L) in meter
1	<800
2	800 m up to but not including 1200 m
3	1200 m up to but not including 1800 m
4	1800 m & over

FAA Classification: Based on Aircraft Approach Speed.

Approach Category	Approach Speed Knots (1 knots = 1.9 km/hr)
A	< 91
B	91 - 120
C	121 - 140
D	141 - 165
E	165 or greater

Airport Classification

Based on Function.

- Civil Aviation: International & Domestic
- Military Aviation

Classification Based on Pavement Strength

Code	Single Isolated Wheel Load in kg	Wheel Pressure kg/m2
1	45360	8.4
2	34020	7.0
3	27220	7.0
4	20410	7.0
5	13610	6.0
6	6800	4.90
7	2270	2.90


INDIA
INTERNATIONAL AIRPORTS
N
TAJIKISTAN
AFGHANISTAN
PAKISTAN
CHINA
(TIBET)
NEPAL
BHUTAN
BANGLADESH
MYANMAR
SRI LANKA
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
Amritsar
Delhi
Lucknow
Varanasi
Guwahati
Imphal
Ahmedabad
Kolkata
Bhubaneswar
Mumbai
Hyderabad
Visakhapatnam
Panaji
Bangalore
Chennai
Mangalore
Coimbatore
Tiruchchirappalli
Cochin
Thiruvananthapuram
LEGEND
International Boundary
State Boundary
International Airports
Map not to Scale
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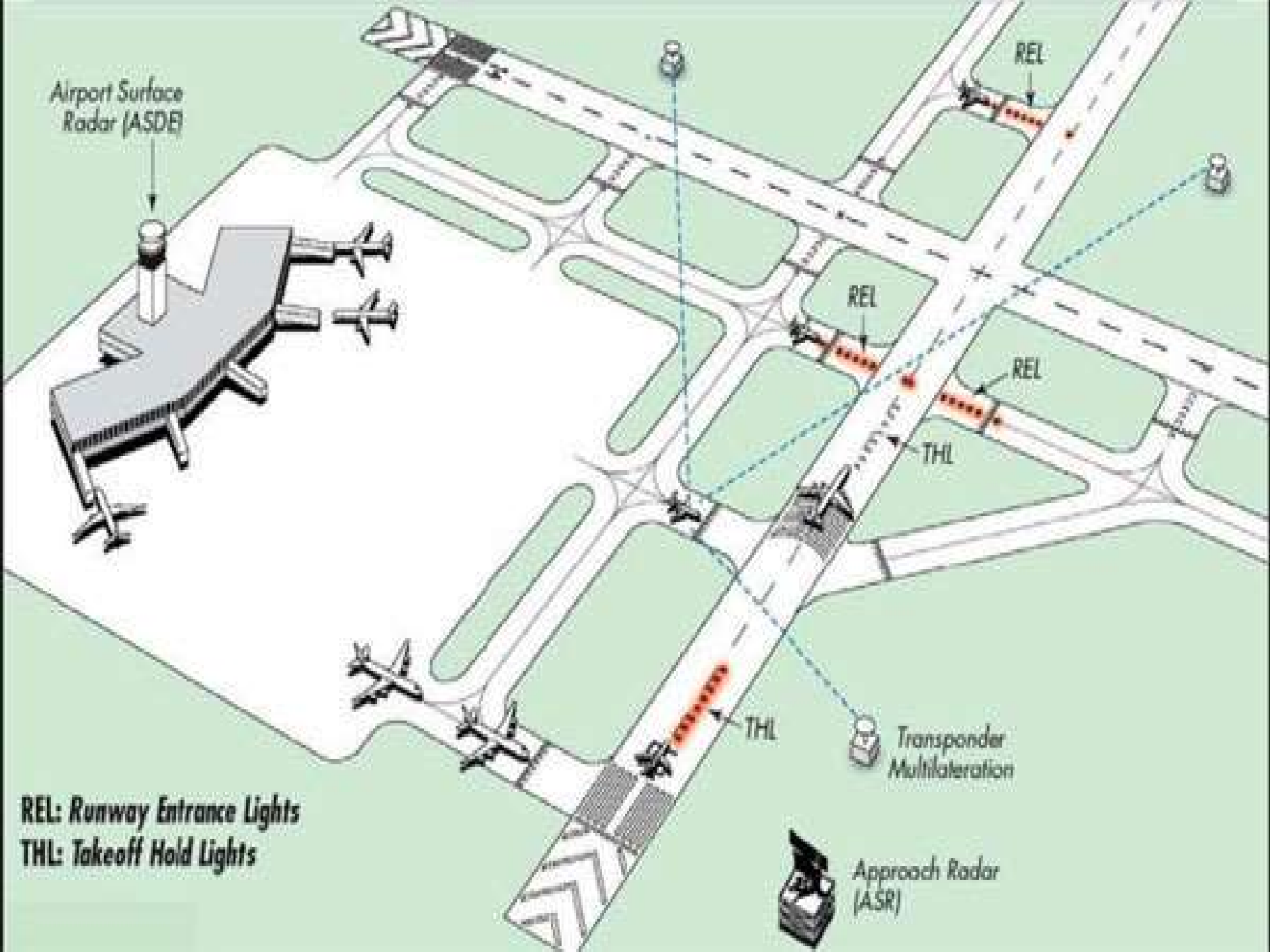
(Updated on 31st October 2013)


Airport Surface Radar (ASDE)
REL
REL
REL
THL
THL
Transponder Multilateration
Approach Radar (ASR)
REL: Runway Entrance Lights
THL: Takeoff Hold Lights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Criteria for airport site selection and ICAO stipulations

The selection of a suitable site for an airport depends upon the class of airport under consideration. However if such factors as required for the selection of the largest facility are considered the development of the airport by stages will be made easier and economical. The factors listed below are for the selection of a suitable site for a major airport installation:

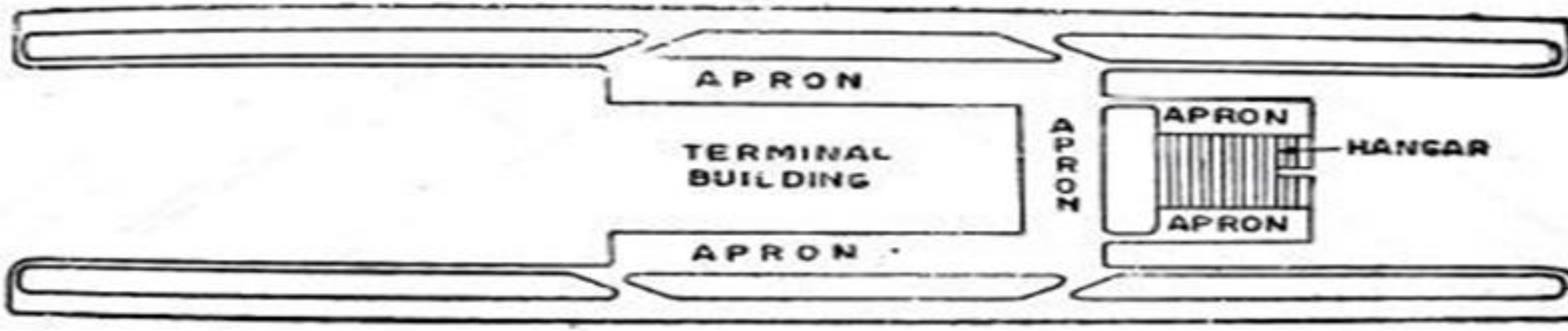
1. Regional plan
2. Airport use
3. Proximity to other airport
4. Ground accessibility
5. Topography
6. Obstructions
7. Visibility
8. Wind
9. Noise nuisance
10. grading, drainage and soil characteristics
11. Future development
12. Availability of utilities from town
13. Economic consideration

Typical airport layouts:

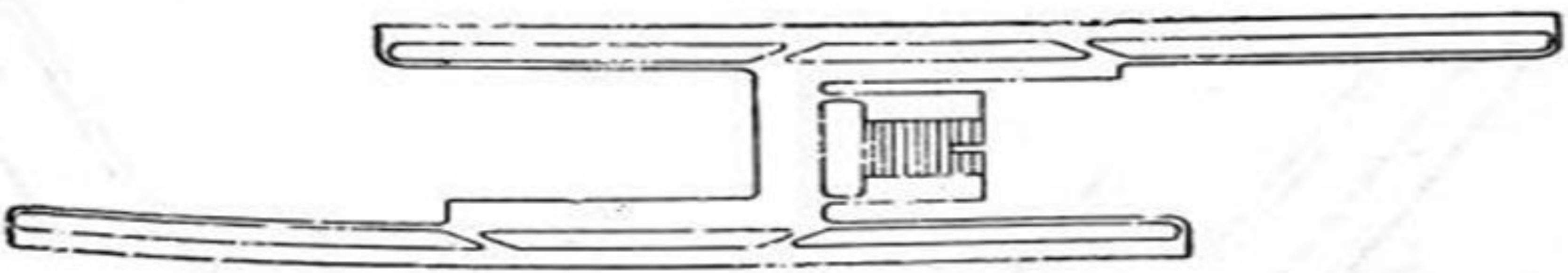
The layout of an airport mainly depends on the basic configurations of the runways. The other airport elements are then correlated in such a way that an integrated layout is developed giving smooth flow of traffic, keeping in mind the taxi distances to a minimum, providing shortest route for the passengers. A proper airport layout provides full functional efficiency with the minimum space utilization. An engineer should attempt to provide the simplest design which yields the optimum service to air passengers. A good airfield layout should posses the following characteristic:

- Landing, taxing and taking off as independent operations without interference.
- Shortest taxiway distance from loading runway end.
- Safe runway length
- Safe approaches
- Excellent control tower visibility
- Adequate loading apron space
- Sufficient terminal building facilities
- Sufficient land area to permit subsequent expansion
- Lowest possible cost of construction.

Single Runway Concept



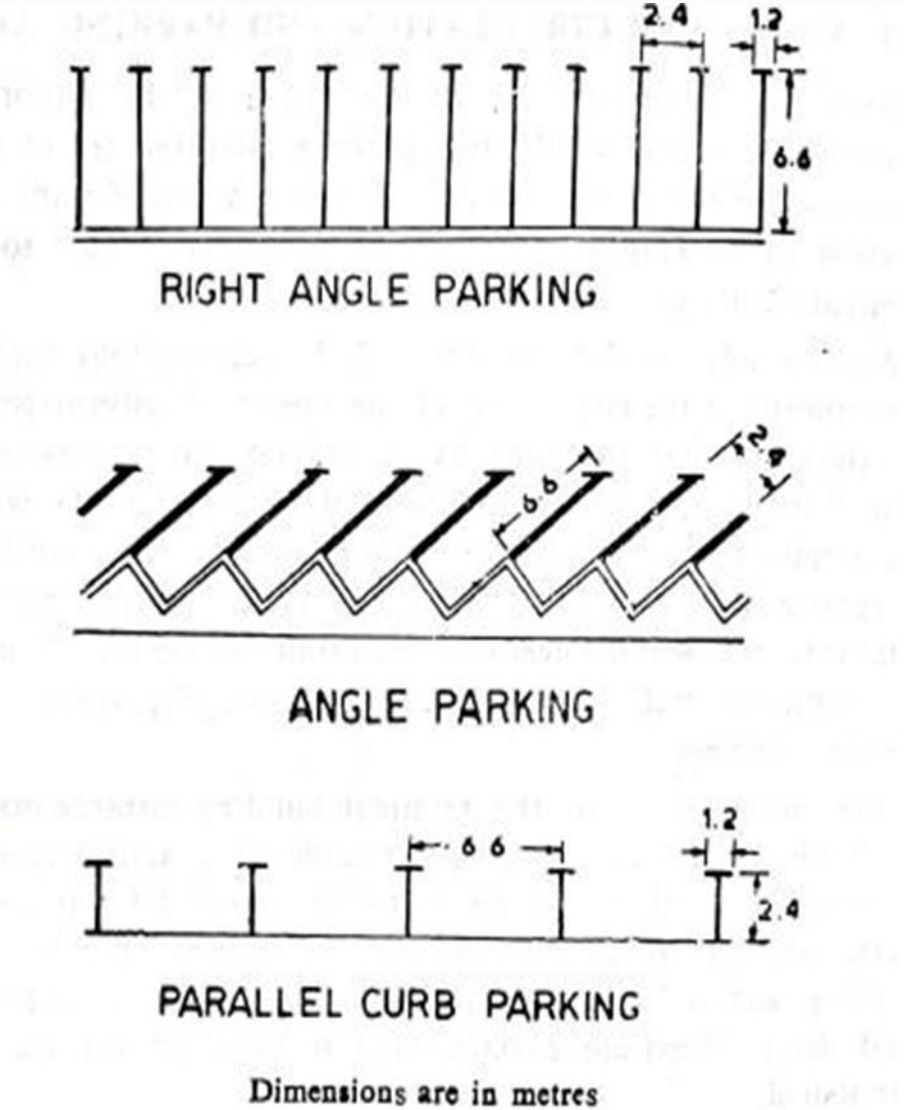
Open Parallel Concept



Offset Parallel Concept

Parking and circulation area

- Ease of passenger unloading and loading at the terminal building
- One way traffic wherever possible
- A minimum of driveway intersection
- Adequate driveway width to permit overtaking
- Sufficiently and clearly defined parking and circulation routes
- Well lighted routes for pedestrians and vehicles



Basic Vehicular Parking Patterns

✈Runway Orientation…

✈ **The orientation of a runway depends upon the <u>direction of wind</u> & <u>to some extent on the area available for development</u>.**

✈**Runway are always orientated in the direction of prevailing wind.**

✈**Determination of a runway orientation is a critical task in the planning & design of an airport.**

✈**The direction of the runway controls the layout of the other airport facilities, such as passengers terminals, taxiways/apron configurations, circulation roads & parking facilities.**

✈Cross wind component

✈ It is not possible to obtain the direction of wind along the direction of the centre line of runway throughout the year, On some day of the year or hour of the day, the wind may blow making certain angle with the centre line of runway.

✈If the direction of wind is at an angle to the runway will be $V\cos\alpha$ & that normal to the runway centre line will be $V\sin\alpha$ where V is the wind velocity.

✈The normal component of the wind is called cross wind components

The maximum permissible cross wind component

✈It depends upon the size of the aircraft and the wind configuration.

FAA - 15 kmph for small aircrafts

- 25 kmph for mixed traffic

ICAO – 35 kmph for big aircrafts

Runway Orientation

- Wind Direction

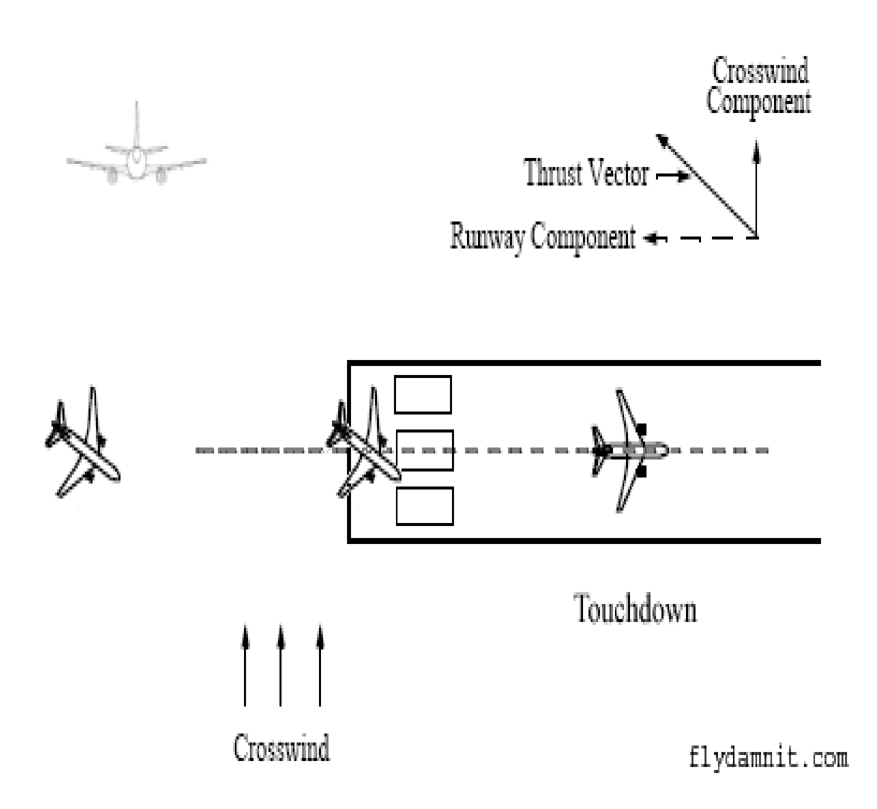
✈**Wind Coverage:** Wind coverage or usability factor of airport is the percentage of time in a year during which the cross wind component remains within the limits as specified above is **wind coverage.**

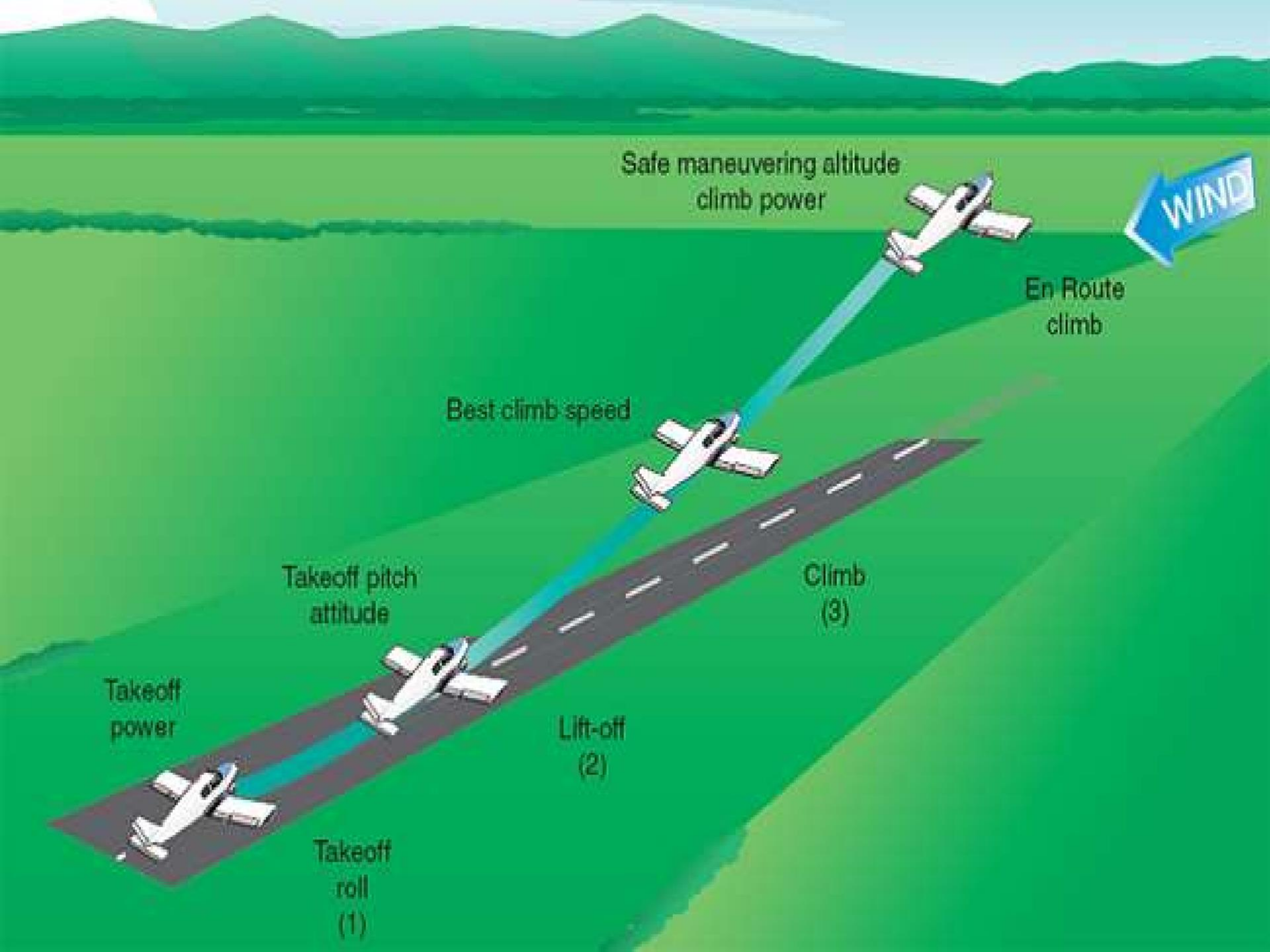
✈ **Calm Period:** This is the period for which the wind intensity remains **below 6.4 km/hr.**

✈This is common to all direction & hence can be added to wind coverage for that direction.

Calm period =

100 – Total wind coverage

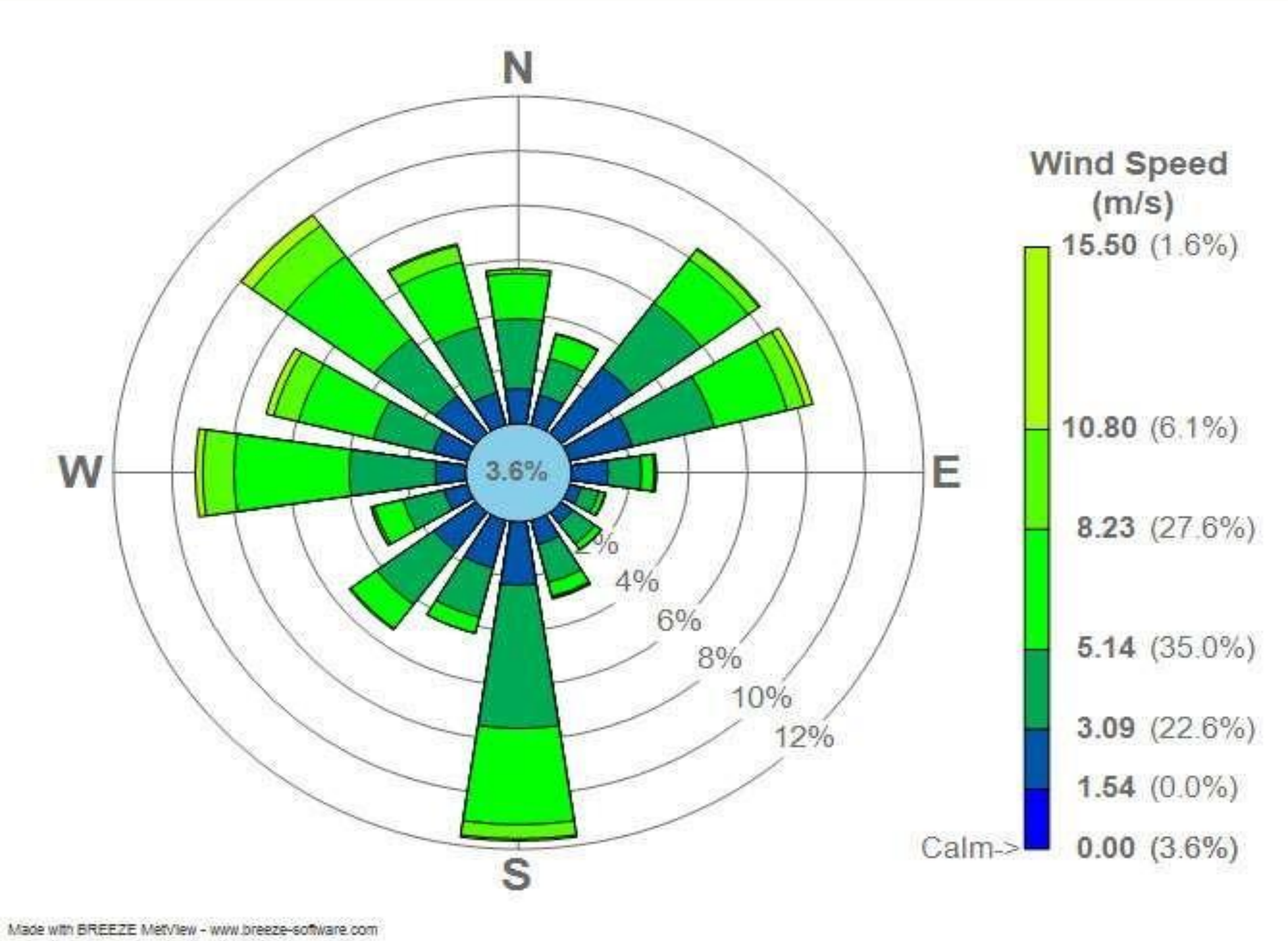




Safe maneuvering altitude
climb power
WIND
En Route
climb
Best climb speed
Takeoff pitch
attitude
Climb
(3)
Takeoff
power
Lift-off
(2)
Takeoff
roll
(1)

Wind Rose…

- The wind data i.e <u>direction, duration & intensity are graphically represented by a diagram</u> called wind rose diagram.
- Application of Wind Rose diagram is for finding the orientation of the runway to achieve wind coverage.
- The area is divided in to <u>16 parts using an angle of 22.5^0</u> .
- Average <u>wind data of 5 to 10 years</u> is used for preparing wind rose diagram.


N
W
E
S
3.6%
2%
4%
6%
8%
10%
12%
Wind Speed (m/s)
15.50 (1.6%)
10.80 (6.1%)
8.23 (27.6%)
5.14 (35.0%)
3.09 (22.6%)
1.54 (0.0%)
Calm->
0.00 (3.6%)
Made with BREEZE MetView - www.breeze-software.com

Wind Rose – Methods;

- Type – I: Showing direction & duration of wind.
- Type –II: Showing direction, duration & intensity of wind.

Type – I : Showing direction & duration of wind.

- The radial lines indicate the wind direction and each circle represents the duration of wind.
- From the wind data it is observed that the total % of time in a year during which the wind blows from north direction is 10.3%.
- This value is plotted along the north direction in figure.
- Similarly other values are also plotted along the respective directions.
- All plotted points are then joined by straight lines.
- The best direction of runway usually along the direction of the longest line on wind rose diagram.
- In the figure the best orientation of runway is NS direction.

Table 6.1 Wind Data*

Wind direction	Duration of wind, per cent**			Total in each direction percent
	6.4 – 25 kmph	25 – 40 kmph	40 – 60 kmph	
N	7.4	2.7	0.2	10.3
NNE	5.7	2.1	0.3	8.1
NE	2.4	0.9	0.6	3.9
ENE	1.2	0.4	0.2	1.8
E	0.8	0.2	0.0	1.0
ESE	0.3	0.1	0.0	0.4
SE	4.3	2.8	0.0	7.1
SSE	5.5	3.2	0.0	8.7
S	9.7	4.6	0.0	14.3
SSW	6.3	3.2	0.5	10.0
SW	3.6	1.8	0.3	5.7
WSW	1.0	0.5	0.1	1.6
W	0.4	0.1	0.0	0.5
WNW	0.2	0.1	0.0	0.3
NW	5.3	1.9	0.0	7.2
NNW	4.0	1.3	0.3	5.6

Total per cent = 86.5

*Average of 8 years periods.

**Percentage of time during which wind intensity, is less than 6.4 kmph is 100—86.5 = 13.5 percent. This period is called calm period and does not influence the operation of landing or take-off because low wind intensity.

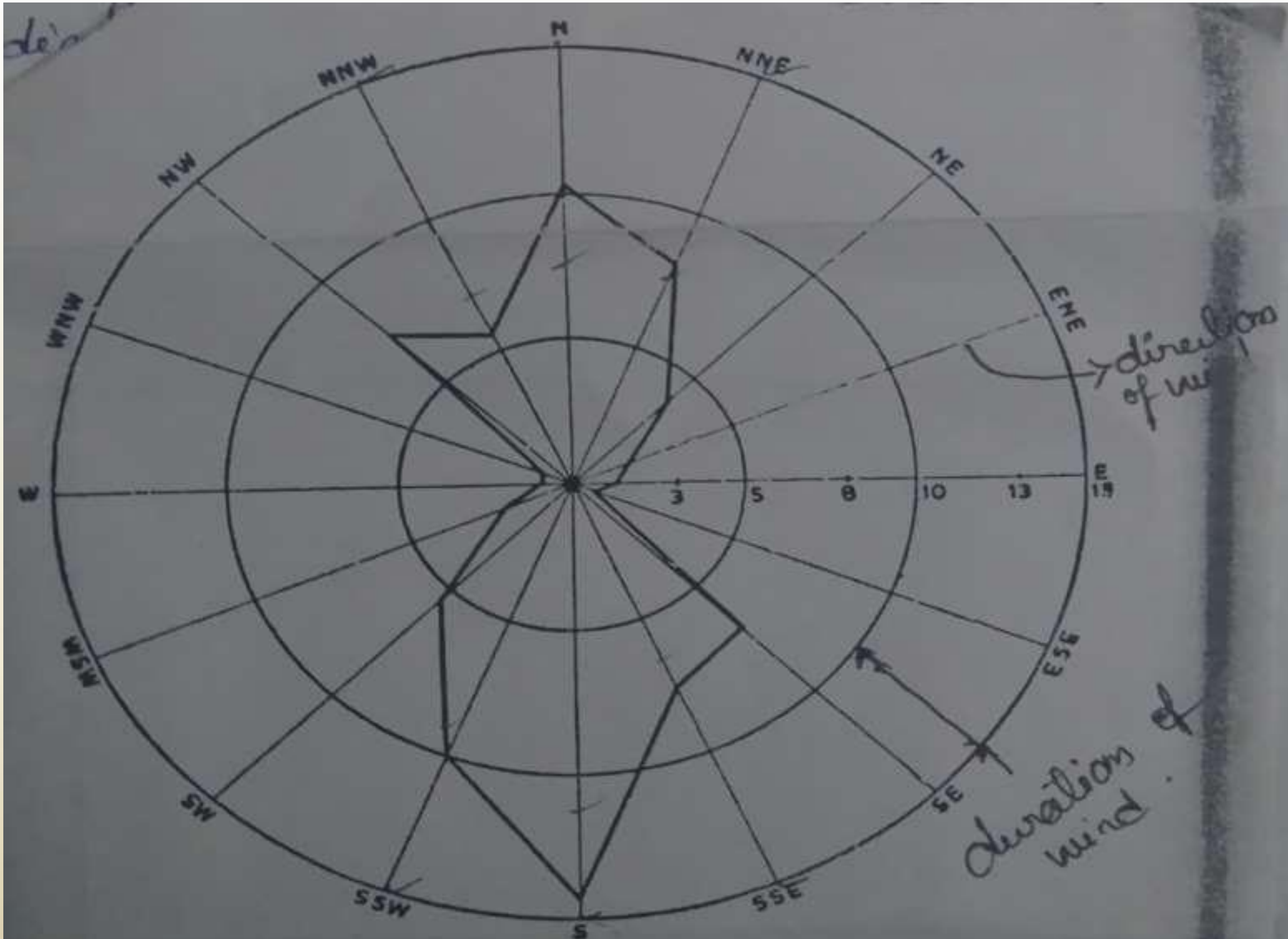


Figure 6.2 Wind Rose Diagram Type I

Type –II :Showing direction, duration & intensity of wind.

- **Each circle represents the wind intensity to some scale. The values entered in each segment represents the % of time in a year during which the wind having a particular intensity.**
- **Procedure: draw 3 equi-spaced parallel lines on a transparent paper strip.**
- **Place the transport paper strip over the wind rose diagram in such a way that the central line passes through the centre of the diagram.**
- **With the centre of wind rose, rotate the tracing paper & place it in such a position that the sum of all the values indicating the duration of wind, within the two outer parallel lines, oriented is the maximum.**
- **The runway should be thus oriented along the direction indicated by the centre line. The wind coverage con be calculated by summing up all the % shown in segment.**
- **Read the bearing of the runway on the outer scale of the wind rose where the central line on the paper. That is the best orientation of runway.**

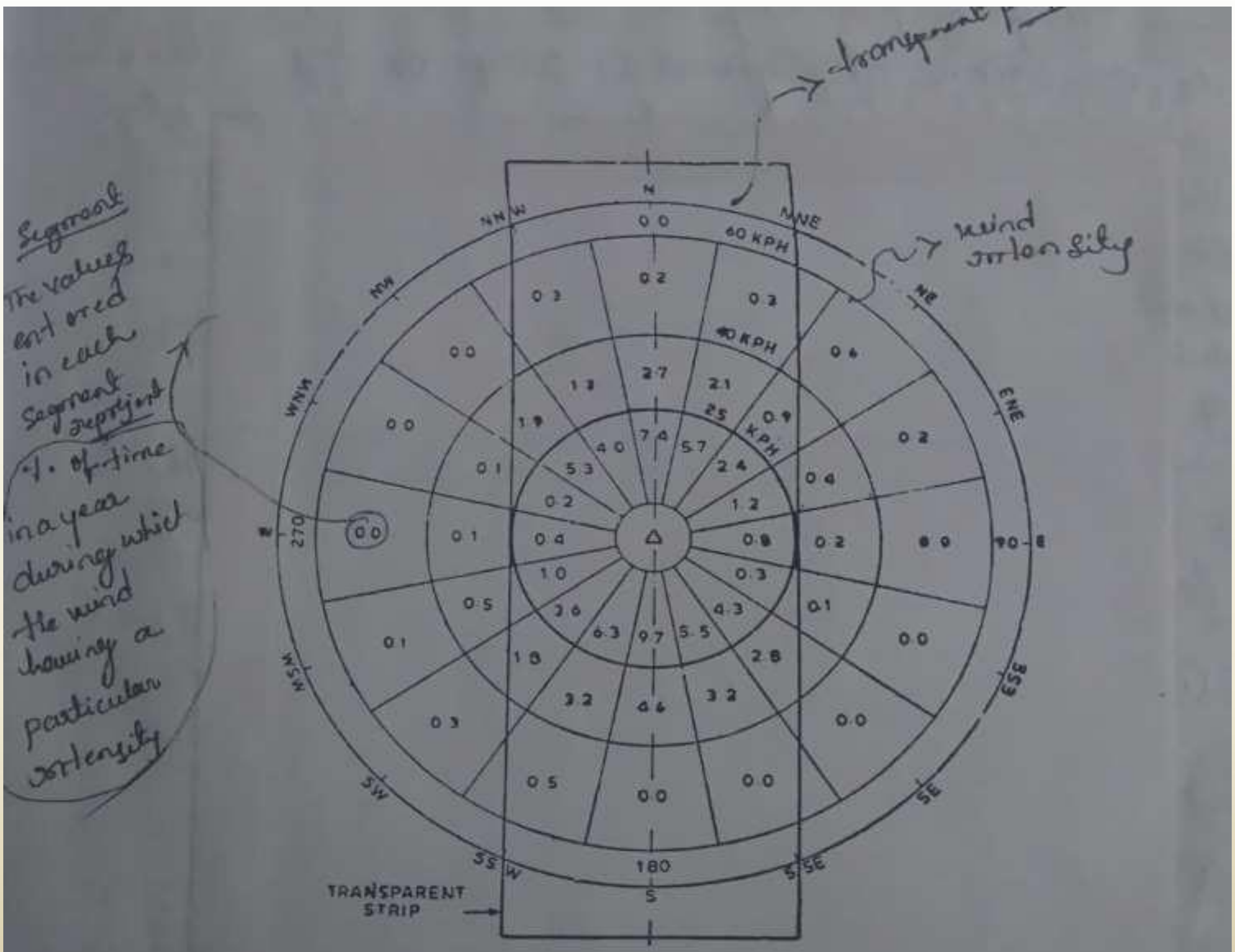


Figure 6.3 Wind Rose Diagram. Type II


SpiceJet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