Advanced Transportation Engineering

7th Semester B Tech (Civil Engineering)

Course Code- PECE5405

Syllabus

MODULE-I

History of Indian railways, component parts of railway track, problems of multi gauge system, coning of wheels, alignments and survey, permanent way track components, Type of rail sections, creep of rails, wear and failure in rails , Ballast requirements, sleeper requirements, types of sleepers, various train resistances

MODULE-II

Geometric design: Gradients and grade compensation, various speeds on a railway track, super elevation, horizontal and vertical curves, Points and crossings, Design of simple turn-out, signaling and interlocking

MODULE-III

Airport site selection, Air craft characteristics, various surface of an airport, Wind rose diagram, Geometric elements and design of run way and taxiway , holding apron, parking configuration , terminal building , visual aids, air traffic control, airport marking and lighting.

Module-IV

Harbour Engineering: Classification of Harbour basin, general layout of harbours, Docks, Different components of docks, classification of waterways, economics of inland waterways transportation, national waterways

Text Books/Reference Books:

1. A text book of railway engineering By S.C. Saxena and M.G. Arora
2. Railway Engineering by Satish Chandra & MM Agrawal, Oxford University Press.
3. Transportation Engineering, Volume-II- Railways, Airports, Docks and Harbours, Bridges and Tunnels by C. Venkatramaih, Universities Press
4. Air-port Engineering by S.K. Khanna and M.G. Arora

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Module I

History of Indian railways

India was introduced to the rail transport industry (or commonly called Railways) in the early 18th Century by the British Government. In recent times, Indian Railways is an independent body which is operated under the jurisdiction of the Ministry of railways, Government of India that regulates India's national railway system. Indian Railways is the fourth largest network in the world as per its size.

The History of the Railways in India can be classified easily on the basis of different periods from the initial times.

- 1832-1852 : The Period of Industrial Railways
- 1853-1924: The Expansion and Introduction of Passenger Railways
- 1925-1924 :Electrification and further Expansion of Railways
- 1947-1950: The Aftermath of Partition
- 1951-1983: Zonal re-organization and Development of Railways
- 1984-Present: Rapid transit and Later Development of Railways

Permanent way (Railway Track)

The combination of rails, fitted on sleepers and resting on ballast and subgrade are called the railway –track. In a permanent way, the rails are joined in series by fish plates and bolts and then they are fixed to sleepers by fastening. The sleepers properly spaced, resting on ballast, are suitably packed and boxed with ballast. The layer of ballast rests on the prepared subgrade called the formation. The rails act as girders to transmit the wheel load to the sleepers. The sleepers hold the rails in the proper position with respect to the proper tilt, gauge and level, and transmit the load from rails to the ballast. The ballast distributes the load over the formation and holds the sleepers in position. On curved track, super-elevation is maintained by ballast and the formation is levelled. Minimum ballast cushion is maintained at the inner rail. Outer rail gets more ballast cushion.

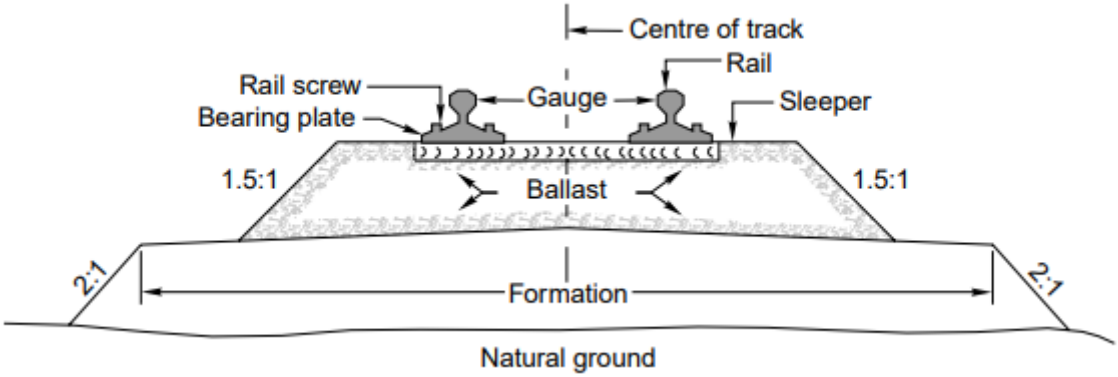

Fig. 1 Typical cross-section of a permanent way on an embankment.

Requirements of an Ideal Permanent Way

- The gauge should be correct and uniform,
- The rails should be in proper level. In a straight track, two rails must be at the same level. On curves, the outer rail should have proper superelevation and there should be proper transition at the junction of a straight and a curve.
- The alignment should be correct. It should be free from kinks or irregularities.
- The gradient should be uniform and any change of gradient should be followed by a smooth vertical curve.
- The track should be resilient, there must be a certain amount of elasticity in the track.
- (vi) The track should have enough lateral strength, so that alignment is maintained even due to (a) side thrust on tangent lengths and centrifugal force on curves (fr) lateral forces due to expansion of rails, particularly welded rails.
- The radii and superelevation on curves should be properly designed and maintained.
- Drainage system must be perfect.
- Joints, including points and crossings which are regarded be weakest points of the railway track, should be properly designed and maintained.
- If there is trouble from the creep, the precaution should be taken to prevent it,
- Various components of the track, i.e., the rails, fittings, sleepers, ballast and formation must fully satisfy the requirements for which they have been provided. If any component is lacking in fulfilling its requirements then either it should be improved or replaced.
- There should be adequate provision for easy renewals and replacements.

Gauges in Railway Track.

The Gauge of a railway track is defined as the clear distance between inner or running faces of

two track rails. The distance between the inner faces of a pair of wheels is called the "wheel gauge".

In India the existing gauges are:

Standard gauge (B.G.) =1.676 m.

Metre gauge (M.G.) = 1.0m.

Narrow gauge (N.G.) =0.762 m

Feeder track-gauge or Light gauge (L.G.) =0.610 m

Selection of Gauge:

Cost of Construction.

There is little increase in the initial cost if we select a wider gauge (say B.G*)» This is due to following reasons :

Cost of bridges, tunnel, station buildings, staff quarters, signals, cabins and level crossings is the' same for all the gauges.

The cost of earth work, (in making embankments and cuttings) ballast, sleepers, rails, etc. would proportionally, increase with gauge width.

The cost of rolling stock is independent of the gauge used for the same volume of traffic.

We can, therefore, conclude that there is not an appreciable increase in cost due to increase in width of gauge.

Volume and Nature of Traffic.

It is evident that with greater traffic volume and greater load carrying capacity, the trains should be run by a better traction technique or by better locomotives. For heavier loads and high speed, the wider gauges are required because subsequently the operating cost per tonne-km. is less for more carrying capacity.

Development of the Areas.

Narrow gauges can be used to develop the thinly populated areas by joining the poor developed areas with developed urban areas.

Physical Features of the Country.

Use of Narrow gauge is warranted in hilly regions where broad and metre gauges are not possible due to steep gradients and sharp curves.

Speed of Movement. The speed of train is proportional to the gauge. Speed is the function of dia of wheel, which in turn limited by the gauge. The wheel diameter .is generally 0-75 times that of the gauge. Lower speeds discourage the customers, and so for maintaining high speeds, the Broad gauges are preferred.

Uniformity of gauge

- The delay, cost and hardship in transshipping passengers and goods from the vehicles of one gauge to another is avoided.
- As the transshipping is not required there is no breakage of goods.
- Difficulties in loading and unloading are avoided and labour expenses are saved.
- Possibility of thefts and misplacement, while changing from one vehicle to another, is eliminated.
- Large sheds to store goods are not required.
- Labour strikes, etc. do not affect the service and operation of trains.
- Surplus wagons of one gauge cannot be used on another gauge. This problem will not arise if guage is uniform.
- Locomotives can be used on all the tracks if a uniform type of gauge is adopted.
- Duplication of equipment such as platforms, sanitary arrangements, clocks, etc. is avoided. This saves a lot of extra expenditure.

Coning of Wheels.

The distance between the inside edges of wheel flanges is generally kept less than the gauge. So there is a gap between the flanges and running edges to the rail nearly equal to 1 cm. (3/8") on either side. Normally the tyre is absolutely dead center on the head of the rail, as the wheel is coned to keep it in this central position automatically. These wheels arc coned at a slope of 1 in 20.

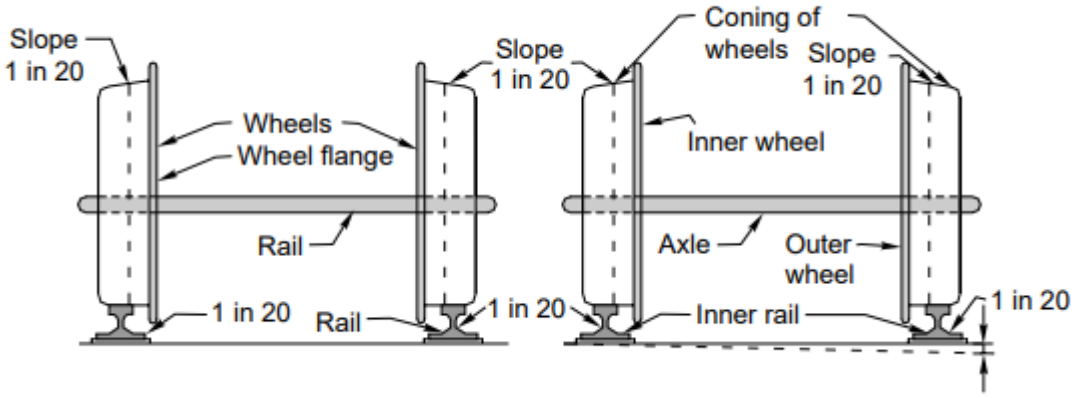

Fig. 2 Coning of wheels

The advantages of coning the wheels are;

- To reduce the wear and tear of the wheel flanges and rails, which is due to rubbing action of flanges with inside faces of the rail head.
- To provide a possibility of lateral movement of the axle with its wheels.

- To prevent the wheels from slipping to some extent.

Rails

The rails on the track can be considered as steel girders carrying axle loads.

Functions of Rails:

- Rails provide a hard, smooth and unchanging surface for passage of heavy moving loads with a minimum friction between the steel rails and steel wheels,
- Rails bear the stresses developed due to heavy vertical loads, lateral and braking forces and thermal stresses.
- The rail material is such that it gives minimum wear to avoid replacement charges and failures of rails due to wear.
- Rails transmit load to sleepers and consequently reduce pressure on ballast and formation.

Composition of Rail Steel.

(a) For Ordinary Rails.

Carbon (C) — 0.55 to 0.68 per cent Manganese (Mn)— 0.65 to 0.90 per cent Silicon (Si) — 0.05 to 0.3 per cent Sulphur (S)— 0.05 per cent or below Phoshorus (P)— 0.05 per cent or below'

(b) For Ralls on Points and crossings.

Carbon (C) — 0.5 to 0.6 per cent Manganese (Mn) — 0.95 to 1.25 per cent Silicon (Si)—0.05 to 0.20 per cent Sulphur (S) — 0.06 per cent or below Phosphorus (P) — 0.06 per cent or below

Requirements of Rails

- They should be of proper composition of steel as given above 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. The height of rail should, therefore, be adequate.
- Rails should be capable of withstanding lateral forces. Large width of head and foot endows the rails with high lateral stiffness.
- The head must be sufficiently deep to allow for an adequate margin of vertical wear. The wearing surface should be hard.
- Web 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 against overturning.
- Bottom of the head and top of the rails foot should be so shaped as to enable the fish

plates to transmit efficiently the vertical load from the head to the foot at rail joints.

- Relative distribution of material in head, web and foot of rail must be balanced.
- The centre of gravity of the rail section must lie approximately at mid-height so that maximum tensile and compressive stresses are equal.
- Fillet radii must be large to reduce the concentration oi stresses.
- The rail specimen should withstand the blow of falling weight in test (as specified by Indian Railway Standards without fracture).

Types of Rail Sections.

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

Table1 Comparison between types of rails

Point of comparison	**Flat-footed Rails**	**Bull-headed Rails and Double-headed Rails**
Strength and stiffness	These have more strength and stiffness for the same weight, both laterally and vertically.	These have less strength and stiffness.
Laying and Re-laying	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.
Arrangements at points, cross-ings and at sharp curves	simpler	complicated
Alignment and stability	impact of Rolling wheels affects the fittings, and the loosening of fittings dis- turbs the alignment and gives less stability	Rails when fitted on chairs, provide a more solid, smooth track and better alignment.
Initial cost	These rails require less and cheaper fastenings, so the cost is less.	These require more and costly fastenings and hence cost is more
Rigidity	These rails can be used, without bearing plates, on sleepers as these rails are strong as ar as vertical loads are concerned. Hence they are more rigid.	It is less rigid.
Inspection	Daily inspection is not necessary as no special risk is there.	Daily inspection of wooden keys is necessary.

Maintenance	The maintenance cost is less.	It requires heavy maintenance cost.

Rail Failures

The sudden failure of a rail is generally due to defects in its manufacture, although the other causes may also exist. Two such other causes, which are common, are (/) an abrupt change of section of rail, (//) notches with corners in the foot of the rails. Such failures, though rare on Indian Railways, may occur in one or more of the following forms

Crushed Heads

Crushed heads are those which have sagged or flattened. Besides the defect of manufacture, crushed heads are due to (a) slipping of wheels, (b) flat spots on wheels 'which arc developed due to skidding of wheels, (c) weak support at the rail end. This weak end support may be due to loose fish bolts.

Square or Angular treak

The rail may be completely broken either in a vertical plane or in an inclined plane.

Split Heads

In this, cracks occur in the middle of the head or pieces are split from the side to the end of the head. If the surfaces of the crack, when opened, appear smooth and dark, the defective rail is known as '"piped rail'" and this is due to cavity formed during manufacture or shrinkage of metal due to the metal not having been closely welded together.

Split Web

This is the through crack in the web, though not necessarily, run through bolt holes.

Horizontal Fissures

These are developed in the rail head. They are more in the form of a fracture and develop gradually.

Transverse Fissures

This is the most common cause of rail failures in America. It is a cross wire crack which starts from a point inside the head and spreads like contours shape gradually. The broken surface has a smooth oval or round bright spot. This defect is a manufacturing defect or may be due to overstraining of metal in service.

Flowing Metal in Heads

The metal in the head is forced to the sides, the rail head being widened and depressed.

Horizontal Cracks

These occur at rail ends between head and web. Such cracks are believed to be due to worn fish plates or insufficient ballast packing under joint sleepers, resulting in pumping of joints and consequent fatigue failure of steel. This defect is very common in rails in America and is increasing day bv day. This defect is either due to fatigue caused by shearing stresses or due to reversal of stresses (from high compressive to low tensile stresses) in the rail between supports.

Creep of rails

Creep is defined as the longitudinal movement of rails with respect to sleepers in a track.

Indications of Creep

- Closing of successive expansion spaces at rail joints in the direction of creep and opening out of joints at the point from where the creep starts.
- Marks on flanges and webs of rails made by spike heads, by scraping or scratching as the rails slide.

Theories of Creep

Wave Action or Wave Theory

Wave motion is set up by moving loads of wheels. The vertical reverse curve ABC (as shown in Fig. 8.2) is formed in the rails ahead of the wheels, resulting from the rail deflection under the load, is the chief cause of creep. The wheels push the wave with a tendency to force the rail in the direction of traffic. On a particular rail, the joint action by several wheels causes creep. As the wheels move, the lift in front of the moving load is thus carried forward by the wheels and causes creep, whereas the lift at the rear of the wheel gets back to its normal position.

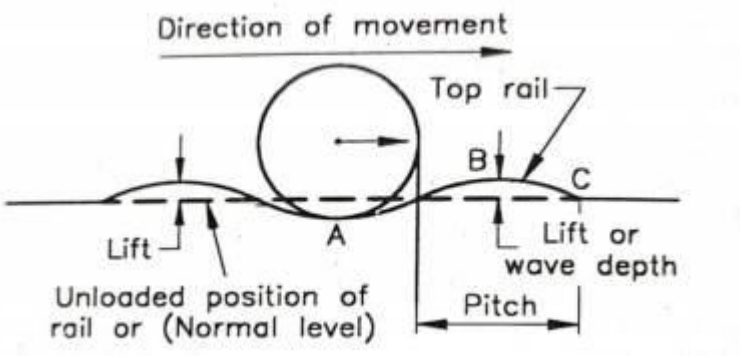

Fig. 3 Wave theory

The wave action can be reduced (i.e. creep is reduced) by adopting following measures:

- Angular and heavy ballast-which develops good interlock
- Increased stiffness of track
- Lesser sleeper spacing
- Bigger, section of the rail

Percussion Theory

This theory states that the creep is due to impact of wheels at the rail end ahead at joints. The horizontal component 'P' of 'R' tends to cause creep while the vertical component tends to bend down the rail end vertically, i.e., to make a battered rail end. Hence as and when the wheels leave the trailing rail and strike the facing rail end at each joint, it pushes the rail forward resulting in creep. Though the creep is very small in single impact but cumulative effect of number of wheels in quick succession results in sufficient creep.

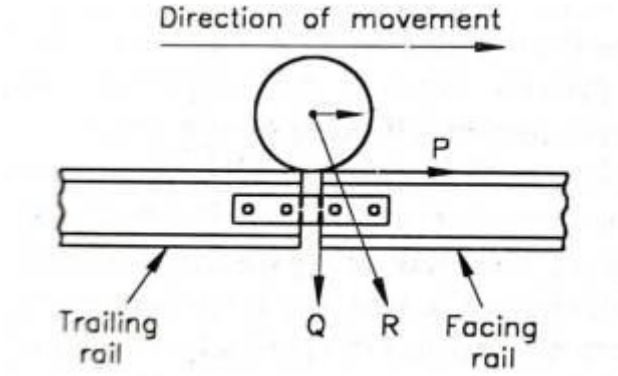

Fig. 4 Percussion Theory

Drag or Dragging Theory

It states that backward thrust on driving wheels of the locomotive of train has got a tendency to push the rail off the track backward while the other wheels of the locomotive and the vehicles (i.e. wheels of coaches and wagons) push the rail in the direction of travel as explained in Wave Action Theory and they have greater effect (as compared to drag effect). This results in creep of rails in the direction of movement of trains.

Starting, Accelerating, Slowing down or Stopping of a Train

When a train is starting or accelerating, the backward thrust of the engine driving wheels tends to push the rails backward. When it is slowing down (i.e. decelerating) or coming to a stop, the braking effect tends to push the rails forward.

Expansion or Contraction of Rails due to Temperature

Creep also occurs due to variation in temperature. The creep in this case is influenced by the range in temperature variation, location of track, whether exposed or shady surroundings, etc.

Unbalanced Traffic

- In a single line system if heavy equal traffic (both in number and load) runs in both directions, the creep is almost balanced. Otherwise, heavy traffic in one direction will cause creep, which is partly balanced by light traffic in opposite direction.

- In the double line system, trains on a particular line being unidirectional, creep occurs in both the lines. The above mentioned causes are main but by no means the only causes of creep.

Effects of Creep

- Sleepers move out of square and out of position. This affects the gauge and alignment of track. As sleepers move, naturally the surface is also disturbed and finally results in an uncomfortable riding.
- Rail-joints are opened out of their limit in some cases and stresses are set up in fish-plates and bolts due to which the bolts sometimes break. The rails are also battered at ends due to excessive gaps at joints. While at other places, joints are jammed and prevent required expansion due to temperature variation.
- Points and crossings get distorted and it becomes very difficult to keep them to correct gauge and alignment. The movement of switches is made difficult (i.e., difficult to operate the switches) and interlocking is thrown out of gear.
- If any rail is removed from the track for any purpose, it becomes difficult to fix it again at proper position because by the time gap becomes too short or too long due to creep.
- Besides these effects, smashing of fish-plates and fish-bolts, bending of bars, kinks at joints of rails and forging of ballast ahead, are common effects of creep.

Rail joints

Rail Joints are necessary to hold together the adjoining ends of rails in the correct position, both in the horizontal and vertical planes. Rail joints form the weakest part of the track.

Requirements of an Ideal Joint.

- An ideal or perfect rail joint IS one which provides the same strength and stiffness as the other section of the track.
- The two rail ends should remain true in line both laterally and vertically when trains move on the track. This is necessary to avoid wheel jumping or changing its correct path of movement.
- It should be as strong and stiff as the rail itself and should be elastic both laterally and horizontally.
- The Rail Joint should provide enough space for free expansion and contraction to account the effect of temperature variations.
- A good joint should be easily disconnectable so that it can be easily taken out without disturbing the whole track for the purpose of changing a rail or fish plate, and

lubricating the contact faces.

- It should not allow the rail ends to get battered in any
- The joint should fulfil the above requirements with the minimum initial and maintenance cost i.e., it should be economical.

Types of Rail Joints.

The following types of joints are commonly used on Indian and foreign railways;

Supported rail joint

When the rail ends rest on a single sleeper called a "joint sleeper" it is termed as "supported rail joint.

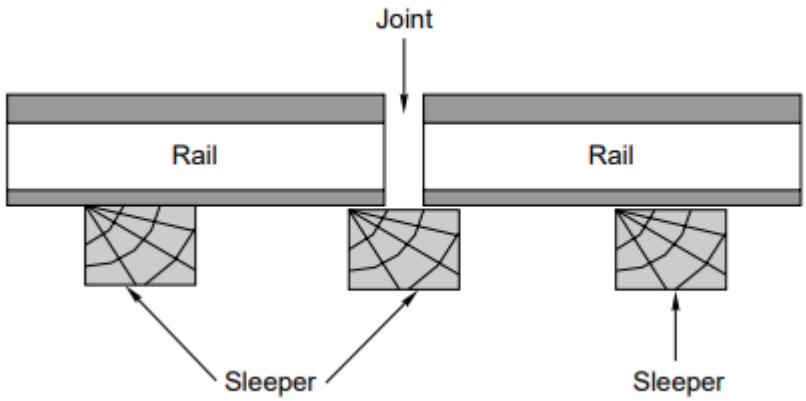

Fig. 5 Supported rail joint

Suspended rail Joint

When rail ends are projected beyond sleepers called "shoulder sleeper", it is termed as suspended joint. This type of joint is generally used with timber and steel trough sleepers on Indian and foreign railways.

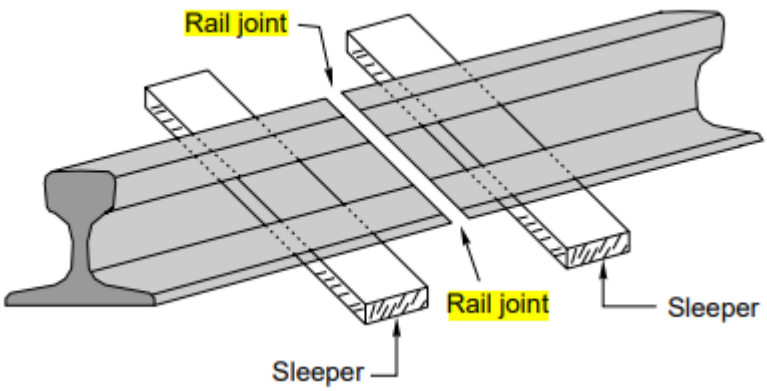

Fig. 6 Suspended rail Joint

Bridge Joint

When the rail ends are projected beyond sleepers as in case of suspended joint and they are carried by a flat or corrugated plate called a “bridge plate”, it is termed as a bridge joint.

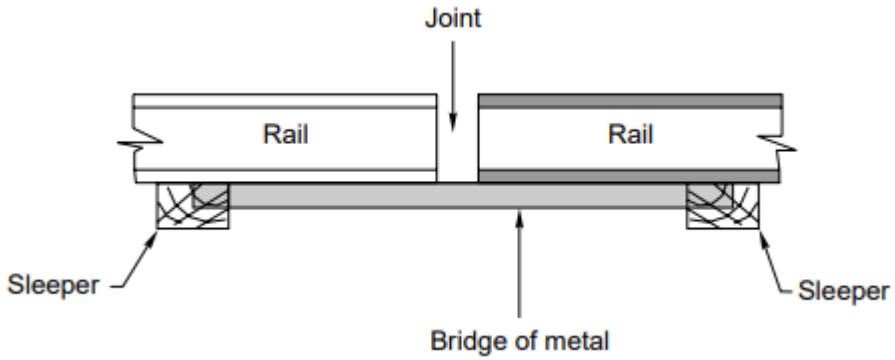

Fig. 7 Bridge joint

Base Joint

This is similar to the bridge joint, with the difference that the inner fish plates are of bar type and outer fish plates are of the special angle type in which the horizontal leg is further extended over the sleepers to be bolted to both bridge plate and sleeper.

Staggered or Broken Joint

In this, position of joints is the basis of its nomenclature, the joints of one rail are not directly opposite to the joint of the other rail.

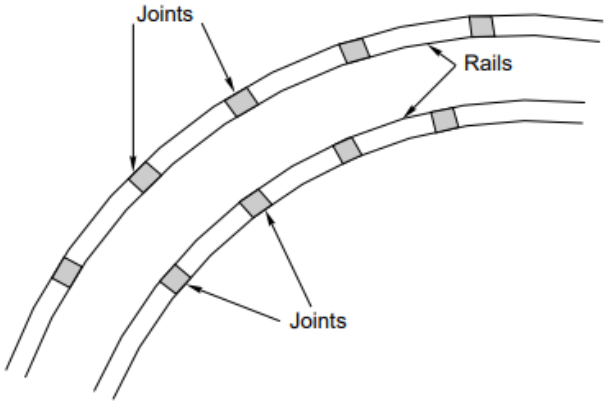

Fig. 8 Staggered joint

Square or Even Joint

In this also, the position of rail joint is the basis of its nomenclature, the joints of one rail of track are directly opposite to the joints ^ of other rail. This is generally used on straight length of track.

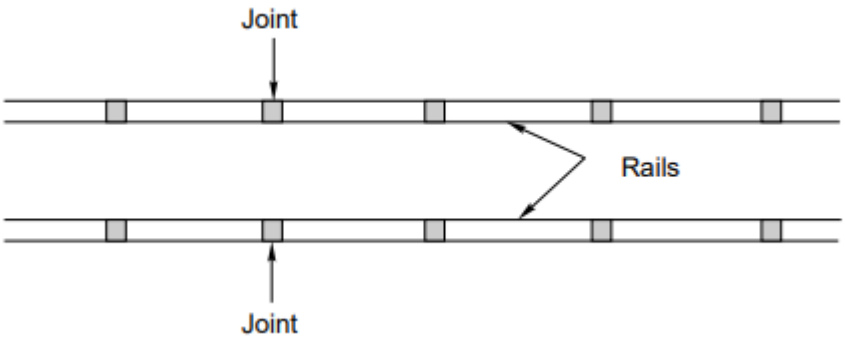

Fig. 9 Square joint

Insulated Joint

When insulating medium is inserted in a rail joint to stop the flow of current beyond the track circuited part called insulated joint.

Welding of rails

Purposes:

- To increase the length of the rail by joining two or more rails and thus to reduce the number of joints, and requirements of fish plates, which lead to economy and strength.
- To repair the worn out or damaged rails and thus increase their life.
- To buildup worn out points and rails on the sharp curves.
- To build up the burnt portion of rail head caused due to slippage of wheels over the rail or other defects or spots in rail steel.

Advantages of Welding of Rail.

- It satisfies the condition of a perfect joint and hence increases the life of the rail and reduces the maintenance cost by about 20 to 40%.
- It reduces the creep as the length of rail increases and friction as a result will also increase.
- Expansion effect due to temperature is also reduced which, also reduces the creep.
- The discontinuity of joint as a source of weakness m track is reduced. The defects such as hammering at rail joints, displacement of joints, disturbance in alignment and running surface, which result in bad riding are eliminated.
- Long rail lengths dampen the intensity of high frequency vibrations due to moving loads.
- Welding increases the life of rails due to decrease in the wear of rails.
- Welding facilitates track circuiting on electrified tracks.
- Welded rails on large bridges for the length of span are helpful as they give better

performance.

- Welded rails on curves is under investigation. Maximum curve radius may be welded depending upon resistance and lateral displacement of track.
- The cost of track construction by welding of rails decreases due to less number of rail joints.

Sleepers

Sleepers are members generally laid transverse to the rails, on which the rails are supported and fixed, to transfer the loads from rails to the ballast and subgrade below.

Functions of Sleepers

- To hold the rails to proper gauge (exact in straight and flat curves, looose in sharp curves and tight in diamond crossings).
- To hold the rails in proper level or transverse tilt.
- To interpose an elastic medium in between the ballast and rails.
- To distribute the load from the rails to the ballast underlying it.
- To support the rails at a proper level in straight tracks and at proper superelevation on curves.
- Sleepers also add to the general stability of the permanent track on the whole.

Requirements of Sleepers

The sleepers to be used should be economical, i.e., they should have minimum possible initial and maintenance costs.

- The fittings of the sleepers should be such that they can be easily adjusted during maintenance operations such as easy lifting, packing, removal and replacement.
- The weight of sleepers should not be too heavy or excessively light, i.e., they should have moderate weight.
- The design of sleepers should be such that the gauge, alignment of track and levels of the rails can be easily adjusted and maintained.
- The bearing area of sleepers below the rail seat and over the ballast should be enough to resist the crushing of the rail seat and crushing of the ballast underneath the sleeper.
- The sleeper design and spacing should be such as to facilitate easy removal and replacement of ballast.
- The sleepers should be capable of resisting shocks and vibrations due to heavy loads of high-speed trains.

Classification of Sleepers.

Sleepers can be classified according to the materials used in their construction, in the following categories:

1. Wooden sleepers
2. Metal sleepers

(a) Cast iron sleepers

(b) Steel sleepers

3. Concrete sleepers

(a) Reinforced concrete sleepers

(b) Prestressed concrete sleepers

Wooden sleepers

Advantages:

- Timber is easily available in all parts of India.
- Fittings for wooden sleepers are few and simple in design.
- These sleepers are able to resist the shocks and vibrations due to heavy moving loads and hence give less noisy track.
- Wooden sleepers are easy to lay, relay, pack, lift and maintain.
- These wooden sleepers are suitable for all types of ballast.
- They are best for track-circuited operations as wooden, sleepers are over-all economic.

Disadvantages:

- The sleepers are subjected to wear, decay, and attack by white ants, spike killing, warping, cracking, end splitting, rail cutting, etc.
- It is difficult to maintain the gauge in case of wooden sleepers.
- Track is easily disturbed, i,e., alignment maintenance is difficult.
- Wooden sleepers have got minimum life (12 to 15 years) as compared to other types of sleepers.
- Maintenance cost of wooden sleepers is highest as compared to other sleepers.

Metal Sleepers.

- Metal sleeper should bear the tensile and compressive stresses which come on them.
- Thev should provide sufficient area for rails, area on ballast should be at least equal to that of wooden sleepers.
- Tamping and packing of ballast should not disturb the sleeper.

Advantages:

- Metal sleepers are uniform in strength and durability.
- In metal sleepers, the performance of fittings is better and hence lesser creep occurs.
- Metal sleepers are economical, as life is longer and maintenance is easier.
- Gauge can be easily adjusted and maintained in case of metal sleepers.
- For metal sleepers, frequent renewal is required.

Disadvantages:

- More ballast is required than other type of sleepers.
- Fittings are greater in number.
- Metals, C.l. or steel, are liable to rust.
- Metal being good conductor of electricity interferes with track circuiting.
- Metal sleepers are unsuitable for bridges, level crossings and in case of points and crossings.
- These sleepers are only suitable for stone ballast.

Steel sleeper

Advantages:

- Steel sleepers are in one piece.
- The fastenings to the sleepers are less in number and simple in nature.
- These have inverted channel section, so light in weight and can be handled easily.
- The gauge, by use of steel sleepers, can be early adjusted and maintained.
- Manufacturing of sleepers can be done by a simple process.
- The life of sleepers is much more than that of wooden sleepers.

Disadvantages:

- In steel sleepers, generally, cracks develop at rail seat, which require the use of saddle plate.
- The sleepers, being of metal, are liable to corrosion.
- The rounded ends of the sleepers do not prevent lateral shift.
- Steel sleepers like wooden sleepers do not act as insulators and hence interfere with track-circuiting.
- The cost of steel sleepers is proportionally more than. wooden sleepers.

Concrete sleeper

Advantages

- These sleepers are free from natural decay and attacks by insects, etc.

- They have maximum life when compared to other sleepers, the life under normal conditions is 40 to 60 years.
- This is not affected by 'moisture, chemical action of ballast, and sub-soil salt.
- High weight of sleepers helps in minimising joint maintenance by providing longer welded lengths, greater stability of the track and better resistance against temperature rise.
- The sleeper have higher elastic modulus and hence can withstand the stresses induced by fast and heavy traffic, and at the same time the stresses in rails and sleepers are reduced.

Disadvantages of Concrete Sleepers:

- The weight of concrete sleeper is as high as 2.5 to 3 times of wooden sleeper, requiring the mechanical appliance for handling.
- These sleepers require pads and plugs for spikes.
- They damage the bottom edge during the packing.
- The scrap value is almost nil

Fastening

Purpose and Types.

Rail fixtures and 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 to sleepers.

The important fittings commonly used in a permanent way arc the following:

(1) Fish Plates

(2) Spikes

Dog spikes, Screw spikes

Round spikes, Standard spikes

Elastic spikes

(3) Bolts

Dog or hook bolt, Fish bolt

Rag bolt, Fang nut and bolt

(4) Chairs

Cast steel chairs, Mild steel and Cast Iron, slide chairs

(5) Blocks

Heel blocks, Distance blocks

Crossing blocks, Check blocks

(6) Keys

Wooden key for M.S. key and steel trough C.l. chair sleepers

Stuart's key, Morgan key, Cotter and tie bars

(7) Plates

Bearing plates, Saddle plates.

Ballast

Ballast is the granular material usually broken, stone or brick, shingle or kankar, gravel or sand placed and packed below and around the sleepers to transmit load (originally from the wheels of the train) from sleeper, to formation and at the same time allowing drainage of the track. It provides a suitable foundation for the sleepers and also holds the sleepers in their correct position, preventing their displacement by lateral or longitudinal thrusts. The lateral stability of a track depends on the ballast.

Functions of Ballast

- Transfers the load from the sleeper to the subgrade and distributes uniformly over a large area of the subgrade.
- It holds the sleepers in position and prevents the lateral and longitudinal movement due to dynamic and vibrating load of moving train.
- It imparts some degree of elasticity to the track.
- It provides easy means of maintaining the correct levels of the two lines in a track, level in straight portions and correct superelevation in curves and correcting track alignment.
- It provides good drained foundation immediately below the sleepers and helps to protect the top surface of the formation. This is achieved by providing coarse and rough aggregate with plenty of voids.

Requirements of the Good Ballast

- It should be able to withstand hard-packing without disintegrating. In other words, it should resist crushing under dynamic loads.
- It should not make the track dusty or muddy due to powder under dynamic wheel loads but should be capable of being cleaned to provide good drainage.
- It should allow for easy drainage with minimum soakage and the voids should be big enough to prevent capillarity.
- It should have resistance to abrasion and weathering. Abrasion means wear due to

rubbing action of particles over each other and weathering means cracking and shattering of the material due to variation in temperature, moisture and freezing. Non-porous particles of ballast ai£ usually more durable.

- It should retain its position laterally and longitudinally under all conditions of traffic particularly on curves where it should prevent transverse displacement of sleepers. The internal friction between particles which provides stability depends upon the size, shape and texture of particles, therefore, angular and cubical stones should be used but not the flat-particles.
- It should not have any chemical action on rail and metal sleepers.
- It should be of size 5 cm for wooden sleepers, 4 cm for metal sleepers and 2'5 cm for turnouts and crossovers using stone ballast,
- The material should be easily workable by means of the implements in use.

Types of Ballast

The different materials used as ballast in India are broken stone, gravel, sand, ashes or cinders, soft aggregates like moorum, kankar, over burnt and broken brickbats, blast furnace slag and sometimes selected earth.

Module II

Geometric design of Track

The geometric design of a railway track includes all those parameters which determine or affect the geometry of the track.

These parameters are as follows

1. Gradients in the track, including grade compensation, rising gradient, and falling gradient.
2. Curvature of the track, including horizontal and vertical curves, transition curves, sharpness of the curve in terms of radius or degree of the curve, cant or superelevation on curves, etc.
3. Alignment of the track, including straight as well as curved alignment.

Necessity for Geometric Design

The need for proper geometric design of a track arises because of the following considerations

(a) To ensure the smooth and safe running of trains

(b) To achieve maximum speeds

(c) To carry heavy axle loads

(d) To avoid accidents and derailments due to a defective permanent way

(e) To ensure that the track requires least maintenance.

Gradients

Gradients are provided to negotiate the rise or fall in the level of the railway track. A rising gradient is one in which the track rises in the direction of the movement of traffic and a down or falling gradient is one in which the track loses elevation in the direction of the movement of traffic. A gradient is normally represented by the distance travelled for a rise or fall of one unit. Sometimes the gradient is indicated as per cent rise or fall. For example, if there is a rise of 1 m in 400 m, the gradient is 1 in 400 or 0.25%

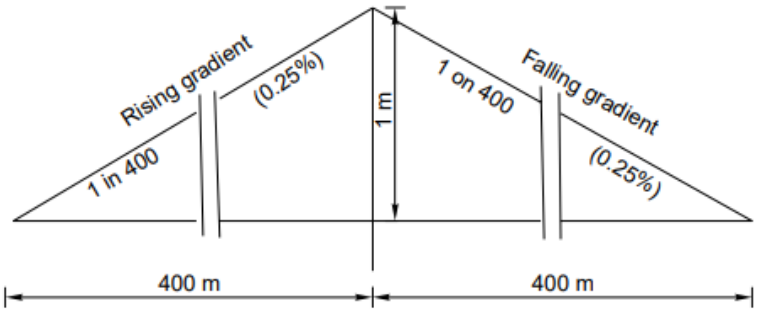

Fig. 10 Rising and falling gradient

Gradients are provided to meet the following objectives. (a) To reach various stations at

different elevations (b) To follow the natural contours of the ground to the extent possible (c) To reduce the cost of earthwork.

The following types of gradients are used on the railways.

(a) Ruling gradient

(b) Pusher or helper gradient

(c) Momentum gradient

(d) Gradients in station yards.

Ruling Gradient

The ruling gradient is the steepest gradient that exists in a section. It determines the maximum load that can be hauled by a locomotive on that section. While deciding the ruling gradient of a section, it is not only the severity of the gradient but also its length as well as its position with respect to the gradients on both sides that have to be taken into consideration. The power of the locomotive to be put into service on the track also plays an important role in taking this decision, as the locomotive should have adequate power to haul the entire load over the ruling gradient at the maximum permissible speed. The extra force P required by a locomotive to pull a train of weight W on a gradient with an angle of inclination θ is

$P = W \sin\theta = W \tan\theta$ (approximately, as θ is very small) = W × gradient

In plain terrain: 1 in 150 to 1 in 250 In hilly terrain: 1 in 100 to 1 in 150

Pusher or Helper Gradient

In hilly areas, the rate of rise of the terrain becomes very important when trying to reduce the length of the railway line and, therefore, sometimes gradients steeper than the ruling gradient are provided to reduce the overall cost. In such situations, one locomotive is not adequate to pull the entire load, and an extra locomotive is required. When the gradient of the ensuing section is so steep as to necessitate the use of an extra engine for pushing the train, it is known as a pusher or helper gradient. Examples of pusher gradients are the Budni–Barkhera section of Central Railways and the Darjeeling Himalayan Railway section.

Momentum Gradient

The momentum gradient is steeper than the ruling gradient and can be overcome by a train because of the momentum it gathers while running on the section. In valleys, a falling gradient is sometimes followed by a rising gradient. In such a situation, a train coming down a falling gradient acquires good speed and momentum, which gives additional kinetic energy to the train and allows it to negotiate gradients steeper than the ruling gradient. In sections with momentum gradients there are no obstacles provided in the form of signals, etc., which may bring the train to a critical juncture.

Gradients in Station Yards

The gradients in station yards are quite flat due to the following reasons. (a) To prevent standing vehicles from rolling and moving away from the yard due to the combined effect of gravity and strong winds. (b) To reduce the additional resistive forces required to start a locomotive to the extent possible. It may be mentioned here that generally, yards are not levelled completely and certain flat gradients are provided in order to ensure good drainage. The maximum gradient prescribed in station yards on Indian Railways is 1 in 400, while the recommended gradient is 1 in 100

Grade compensation on curves

The ruling gradient is maximum gradient on a particular section, but if a curve lies on ruling gradient, the resistance due to gradient is increased by that due to curvature and this further increases the resistance beyond the ruling gradient. In order lo a void resistances beyond the allowable limits, the gradients are reduced on the curves and this reduction of gradients is Known as grade compensation for the curves.

In India, compensation for curvature is given at 0.04% per degree of curve for B.G., 0 03% for M.G. and 0.02% for N.G

Example 1 Find the steepest gradient on a 2° curve for a BG line with a ruling gradient of 1 in 200. Solution (i) Ruling gradient = 1 in 200 = 0.5%

Compensation for a 2° curve = $0.04 \times 2 = 0.08\%$

Compensated gradient = $0.5 - 0.08 = 0.42\%$ = 1 in 238

The steepest gradient on the curved track is 1 in 238

Superelevation

The following terms are frequently used in the design of horizontal curves. Superelevation or cant Superelevation or cant (Ca) is the difference in height between the outer and the inner rail on a curve. It is provided by gradually lifting the outer rail above the level of the inner rail. The inner rail is taken as the reference rail and is normally maintained at its original level. The inner rail is also known as the gradient rail.

The main functions of superelevation are the following.

(a) To ensure a better distribution of load on both rails

(b) To reduce the wear and tear of the rails and rolling stock

(c) To neutralize the effect of lateral forces

(d) To provide comfort to passengers

Equilibrium speed

When the speed of a vehicle negotiating a curved track is such that the resultant force of the

weight of the vehicle and of radial acceleration is perpendicular to the plane of the rails, the vehicle is not subjected to any unbalanced radial acceleration and is said to be in equilibrium. This particular speed is called the equilibrium speed. The equilibrium speed, as such, is the speed at which the effect of the centrifugal force is completely balanced by the cant provided.

Maximum permissible speed

This is the highest speed permitted to a train on a curve taking into consideration the radius of curvature, actual cant, cant deficiency, cant excess, and the length of transition. On curves where the maximum permissible speed is less than the maximum sectional speed of the section of the line, permanent speed restriction becomes necessary.

Cant deficiency

Cant deficiency (Cd) occurs when a train travels around a curve at a speed higher than the equilibrium speed. It is the difference between the theoretical cant required for such high speeds and the actual cant provided. Cant excess Cant excess (Ce) occurs when a train travels around a curve at a speed lower than the equilibrium speed. It is the difference between the actual cant provided and the theoretical cant required for such a low speed.

Cant gradient and cant deficiency gradient

These indicate the increase or decrease in the cant or the deficiency of cant in a given length of transition. A gradient of 1 in 1000 means that a cant or a deficiency of cant of 1 mm is attained or lost in every 1000 mm of transition length.

Rate of change of cant or cant deficiency

This is the rate at which cant deficiency increases while passing over the transition curve, e.g., a rate of 35 mm per second means that a vehicle will experience a change in cant or a cant deficiency of 35 mm in each second of travel over the transition when travelling at the maximum permissible speed.

Equilibrium Superelevation

If θ is the angle that the inclined plane makes with the horizontal line,

Then, $\tan \theta$ =Superelevation/gauge = e/ G

Also, $\tan \theta$ = centrifugal force/weight= F /W

From these equations

e/ G = F /W

$e=GV^2/gR= GV^2/127R$

where e is the equilibrium superelevation, G is the gauge, V is the velocity, g is the acceleration due to gravity, and R is the radius of the curve.

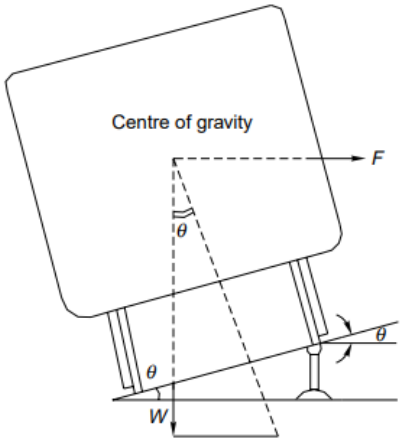

Fig. 11 Equilibrium super elevation

Negative Superelevation

When the main line lies on a curve and has a turnout of contrary flexure leading to a branch line, the superelevation necessary for the average speed of trains running over the main line curve cannot be provided. In Fig. 13.9, AB, which is the outer rail of the main line curve, must be higher than CD. For the branch line, however, CF should be higher than AE or point C should be higher than point A. These two contradictory conditions cannot be met within one layout. In such cases, the branch line curve has a negative superelevation and, therefore, speeds on both tracks must be restricted, particularly on the branch line.

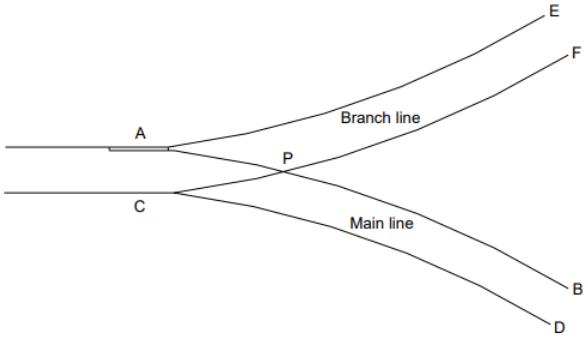

Fig. 12 Negative super elevation

Maximum Permissible speed on a curve.

- The maximum permissible speed on a curve is taken as the minimum value, of the speed calculated by the following methods.
- Maximum sanctioned speed of the section. This is the maximum speed authorized by Additional Commissioner of Railways
- Safe speed over the curve. This is the speed calculated by Martin's formulae based on Gauge type.

- Speed based on the consideration of S.E. This is calculated by formula of equilibrium superelevation, where, the value of superelevation is the sum of full amount of cant deficiency and the actual superelevation.

The above three methods are used for maximum speed determination when the length of transition curve can possibly be increased. But in case, length of transition curve cannot be changed, the following fourth method is also included.

- Speeds from the length of the transition curves. This is the lesser value of the speed given by two following formulae:

For normal speeds upto 100 kmph, Vmax= 134L/e

For high speeds above 100 km. p.h., Vmax= 198L/e

Points and Crossing

Points and crossings are provided to help transfer railway vehicles from one track to another. The tracks may be parallel to, diverging from, or converging with each other.

Important Terms

The following terms are often used in the design of points and crossings. Turnout is an arrangement of points and crossings with lead rails by means of which the rolling stock may be diverted from one track to another. Figure shows the various constituents of a turnout.

Direction of a turnout

A turnout is designated as a right-hand or a left-hand turnout depending on whether it diverts the traffic to the right. The direction of a point (or turnout) is known as the facing direction if a vehicle approaching the turnout or a point has to first face the thin end of the switch. The direction is trailing direction if the vehicle has to negotiate a switch in the trailing direction i.e., the vehicle first negotiates the crossing and then finally traverses on the switch from its thick end to its thin end. Therefore, when standing at the toe of a switch, if one looks in the direction of the crossing, it is called the facing direction and the opposite direction is called the trailing direction.

Tongue rail.

It is a tapered movable rail, made of high-carbon or -manganese steel to withstand wear. At its thicker end, it is attached to a running rail. A tongue rail is also called a switch rail. Stock rail. It is the running rail against which a tongue rail operates.

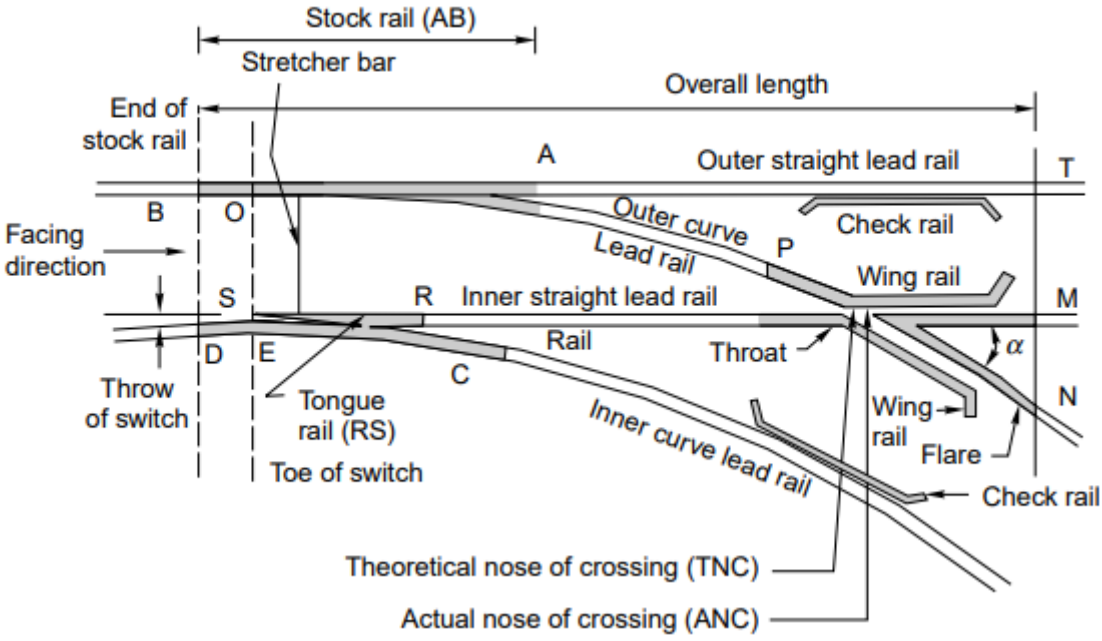

Fig. 13 Turnout

Points or switch

A pair of tongue and stock rails with the necessary connections and fittings forms a switch.

Crossing

A crossing is a device introduced at the junction where two rails cross each other to permit the wheel flange of a railway vehicle to pass from one track to another.

A set of points or switches consists of the following main constituents

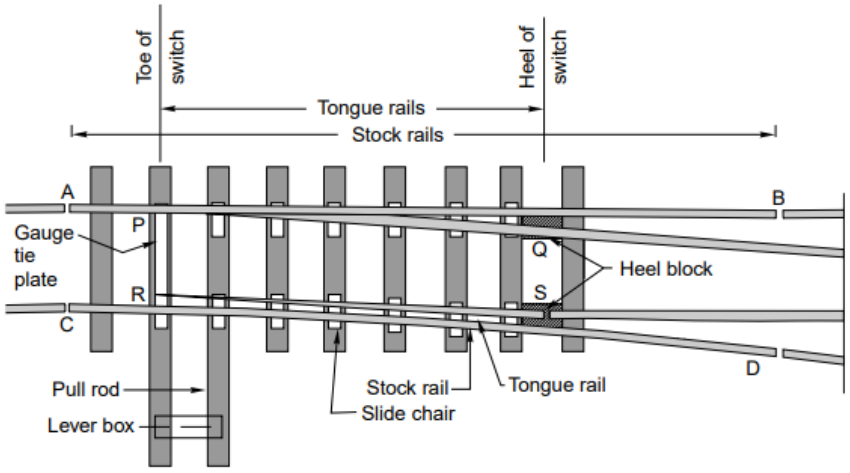

Fig 14 Details of switch

(a) A pair of stock rails, AB and CD, made of medium-manganese steel.

(b) A pair of tongue rails, PQ and RS, also known as switch rails, made of medium-manganese

steel to withstand wear. The tongue rails are machined to a very thin section to obtain a snug fit with the stock rail. The tapered end of the tongue rail is called the toe and the thicker end is called the heel.

(c) A pair of heel blocks which hold the heel of the tongue rails is held at the standard clearance or distance from the stock rails.

(d) A number of slide chairs to support the tongue rail and enable its movement towards or away from the stock rail.

(e) Two or more stretcher bars connecting both the tongue rails close to the toe, for the purpose of holding them at a fixed distance from each other.

(f) A gauge tie plate to fix gauges and ensure correct gauge at the points

Types of Switches

Switches are of two types, namely, stud switch and split switch. In a stud type of switch, no separate tongue rail is provided and some portion of the track is moved from one side to the other side. Stud switches are no more in use on Indian Railways. They have been replaced by split switches. These consist of a pair of stock rails and a pair of tongue rails. Split switches may again be of two types—loose heel type and fixed heel type.

Loose heel type

In this type of split switch, the switch or tongue rail finishes at the heel of the switch to enable movement of the free end of the tongue rail. The fish plates holding the tongue rail may be straight or slightly bent. The tongue rail is fastened to the stock rail with the help of a fishing fit block and four bolts. All the fish bolts in the lead rail are tightened while those in the tongue rail are kept loose or snug to allow free movement of the tongue. As the discontinuity of the track at the heel is a weakness in the structure, the use of these switches is not preferred.

Fixed heel type

In this type of split switch, the tongue rail does not end at the heel of the switch but extends further and is rigidly connected. The movement at the toe of the switch is made possible on account of the flexibility of the tongue rail.

Switch angle

This is the angle between the gauge face of the stock rail and that of the tongue rail at the theoretical toe of the switch in its closed position. It is a function of the heel divergence and the length of the tongue rail.

Flangeway clearance

This is the distance between the adjoining faces of the running rail and the check rail/wing rail at the nose of the crossing. It is meant for providing a free passage to wheel flanges. Table 14.2

gives the minimum and maximum values of flangeway clearance for BG and MG tracks

Heel divergence

This is the distance between the gauge faces of the stock rail and the tongue rail at the heel of the switch. It is made up of the flangeway clearance and the width of the tongue rail head that lies at the heel. **Throw of the switch**

This is the distance through which the tongue rail moves laterally at the toe of the switch to allow movement of the trains. Its limiting values are 95–115 mm for BG routes and 89–100 mm for MG routes.

Crossing

A crossing or frog is a device introduced at the point where two gauge faces cross each other to permit the flanges of a railway vehicle to pass from one track to another (Fig. 14.5). To achieve this objective, a gap is provided from the throw to the nose of the crossing, over which the flanged wheel glides or jumps. In order to ensure that this flanged wheel negotiates the gap properly and does not strike the nose, the other wheel is guided with the help of check rails. A crossing consists of the following components, shown in Fig. Two rails, the point rail and splice rail, which are machined to form a nose. The point rail ends at the nose, whereas the splice rail joins it a little behind the nose. Theoretically, the point's rail should end in a point and be made as thin as possible, but such a knife edge of the point rail would break off under the movement of traffic. The point rail, therefore, has its fine end slightly cut off to form a blunt nose, with a thickness of 6 mm (1/4"). The toe of the blunt nose is called the actual nose of crossing (ANC) and the theoretical point where gauge faces from both sides intersect is called the theoretical nose of crossing (TNC). The 'V' rail is planned to a depth of 6 mm (1/4") at the nose and runs out in 89 mm to stop a wheel running in the facing direction from hitting the nose.

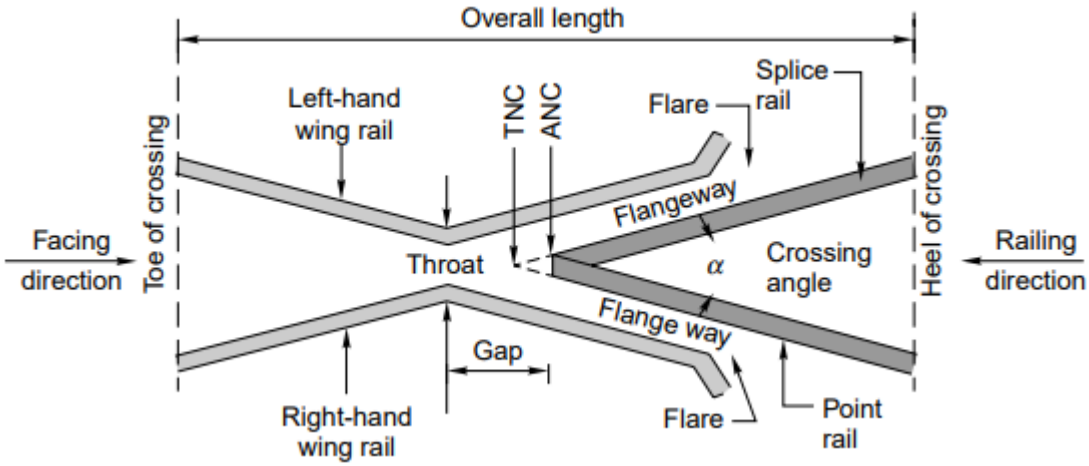

Fig. 15 Details of crossing

Two wing rails consisting of a right-hand and a left-hand wing rail that converge to form a throat and diverge again on either side of the nose. Wing rails are flared at the ends to facilitate the entry and exit of the flanged wheel in the gap.

A pair of check rails to guide the wheel flanges and provide a path for them, thereby preventing them from moving sideways, which would otherwise may result in the wheel hitting the nose of the crossing as it moves in the facing direction.

Types of Crossings

A crossing may be of the following types.

(a) An acute angle crossing or 'V' crossing in which the intersection of the two gauge faces forms an acute angle. For example, when a right rail crosses a left rail, it makes an acute crossing.

(b) An obtuse or diamond crossing in which the two gauge faces meet at an obtuse angle. When a right or left rail crosses a similar rail, it makes an obtuse crossing.

(c) A square crossing in which two tracks cross at right angles. Such crossings are rarely used in actual practice.

Turnouts

The simplest arrangement of points and crossing can be found on a turnout taking off from a straight track. There are two standard methods prevalent for designing a turnout.

These are the (a) Coles method and the (b) IRS method.

Curve lead (CL)

This is the distance from the tangent point (T) to the theoretical nose of crossing (TNC) measured along the length of the main track.

Switch lead (SL)

This is the distance from the tangent point (T) to the heel of the switch (TL) measured along the length of the main track.

Lead of crossing (L)

This is the distance measured along the length of the main track as follows:

Lead of crossing (L) = curve lead (CL) – switch lead (SL)

Angle of crossing-This is the angle between the main line and the tangent of the turnout line.

Radius of turnout (R) This is the radius of the turnout. It may be clarified that the radius of the turnout is equal to the radius of the centre line of the turnout (R1) plus half the gauge width.

$R = R1 + 0.5G$

As the radius of a curve is quite large, for practical purposes, R may be taken to be equal to R1.

Coles method

This is a method used for designing a turnout taking off from a straight track. The curvature begins from a point on the straight main track ahead of the toe of the switch at the theoretical toe of switch (TTS) and ends at the theoretical nose of crossing (TNC). The heel of the switch is located at the point where the offset of the curve is equal to the heel divergence. Theoretically, there would be no kinks in this layout, had the tongue rail been curved as also the wing rail up to the TNC. Since tongue rails and wing rails are not curved generally, there are the following three kinks in this layout.

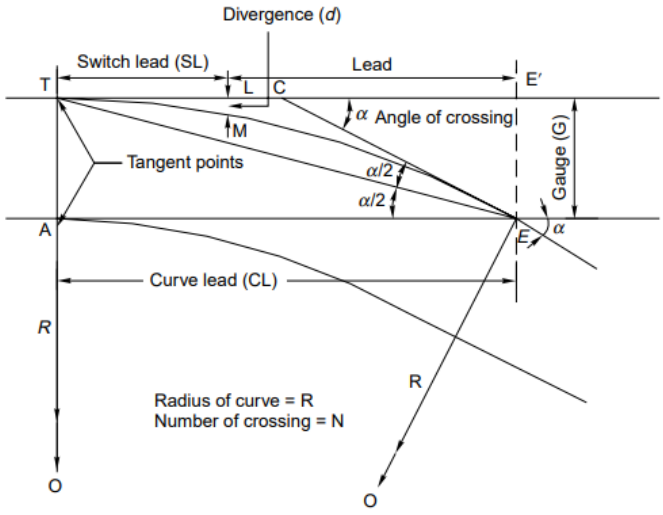

Fig. 15 Turnout from a straight track (Coles method)

$$\text{Curve lead (CL)} = G \cot\frac{\alpha}{2} \text{ or } 2GN \text{ approx.}$$

$$\text{Switch lead (SL)} = \sqrt{2Rd - d^2}$$

$$\text{Lead of crossing } (L) = G \cot\frac{\alpha}{2} - \sqrt{2Rd - d^2}$$

$$= 2GN - \sqrt{2Rd - d^2}$$

$$\text{Radius of curve } (R) = 1.5G + 2GN^2$$

$$\text{Heel divergence } (d) = \frac{(SL)^2}{2\left(R + \frac{G}{2}\right)}$$

IRS method

In this layout, the curve begins from the heel of the switch and ends at the toe of the crossing, which is at the centre of the first distance block. The crossing is straight and no kink is experienced at this point. The only kink occurs at the toe of the switch. This is the standard

layout used on Indian Railways. The calculations involved in this method are somewhat complicated and hence this method is used only when precision is required.

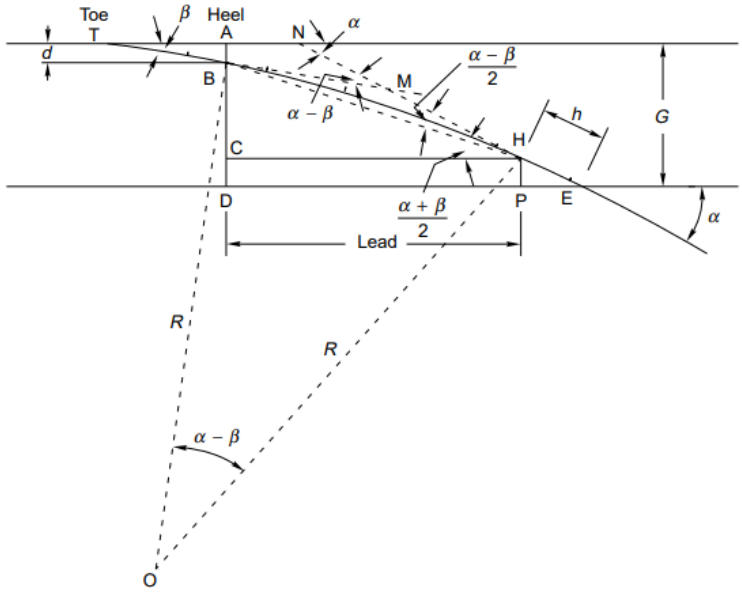

Fig. 16 Turnout from a straight track (IRS method)

$$L = (G - d - h\sin\alpha)\cot\frac{\alpha-\beta}{2} + h\cos\alpha$$

$$R = \frac{G - d - h\sin\alpha}{2\sin\frac{\alpha+\beta}{2}\times\sin\frac{\alpha-\beta}{2}}$$

$$= \frac{G - d - h\sin\alpha}{\cos\beta - \cos\alpha}$$

Track stresses

Lateral forces

The lateral force applied to the rail head produces a lateral deflection and twist in the rail. Lateral force causes the rail to bend horizontally and the resultant torque causes a huge twist in the rail as well as the bending of the head and foot of the rail. Lateral deflection of the rail is resisted by the friction between the rail and the sleeper, the resistance offered by the rubber pad and fastenings, as well as the ballast coming in contact with the rail. The combined effect of lateral forces resulting in the bending and twisting of a rail can be measured by strain gauges. Field trials indicate that the loading wheels of a locomotive may exert a lateral force of up to 2 t on a straight track particularly at high speeds.

Longitudinal forces

Due to the tractive effort of the locomotive and its braking force, longitudinal stresses are developed in the rail. Temperature variations, particularly in welded rails, result in thermal

forces, which also lead to the development of stresses. The exact magnitude of longitudinal forces depends on many variable factors. However, a rough idea of these values is as follows: (a) longitudinal forces on account of 30–40% weight of locomotive of tractive effort for alternating current (ac). (b) Longitudinal forces on account of 15–20% of weight of braking force of the locomotive and 10–15% weight of trailing load. Tensile stresses are induced in winter due to contraction and compressive stresses are developed in summer due to compression. The extreme value of these stresses can be 10.75 kg/mm2 in winter and 9.5 kg/mm2 in summer.

Stresses on a sleeper

The sleepers are subjected to a large number of forces such as dead and live loads, dynamic components of tracks such as rails and sleeper fastenings, maintenance standards, and other such allied factors.

Stresses on ballast

The load passed onto the sleeper from the rail is in turn transferred to the ballast. The efficacy of this load transmission depends not only on the elasticity of the sleeper but also on the size, shape, and depth of the ballast as well as the degree of compaction under the sleeper. The pressure distribution in the ballast under the sleeper and investigations reveal that the pressure distribution curve under the sleeper would be shaped like bulbs. The pressure on the sleeper is maximum at the centre of its width. This pressure decreases from the centre towards the ends. The vertical pressure under the sleeper is uniform at a depth approximately equal to the spacing between the sleepers.

Train Resistance

Resistance Due to Friction

Resistance due to friction is the resistance offered by the friction between the internal parts of locomotives and wagons as well as between the metal surface of the rail and the wheel to a train moving at a constant speed. This resistance is independent of speed and can be further broken down into the following parts.

Journal friction

This is dependent on the type of bearing, the lubricant used, the temperature and condition of the bearing, etc. In the case of roll bearings, it varies from 0.5 to 1.0 kg per tonne.

Internal resistance

This resistance is consequential to the movement of the various parts of the locomotive and wagons. Rolling resistance

This occurs due to rail-wheel interaction on account of the movement of steel wheels on a steel

rail. The total frictional resistance is given by the empirical formula R1 = 0.0016W where R1 is the frictional resistance independent of speed and W is the weight of the train in tonnes

Resistance Due to Wave Action

When a train moves with speed, a certain resistance develops due to the wave action of the train. Similarly, track irregularities such as longitudinal unevenness and differences in cross levels also offer resistance to a moving train. Such resistances are different for different speeds. There is no method for the precise calculation of these resistances but the following formula has been evolved based on experience: R2 = 0.00008WV where R2 is the resistance due to wave action and track irregularities on account of the speed of the train, W is the weight of the train in tonnes, and V is the speed of the train in km/h

Resistance Due to Wind

When a vehicle moves with speed, a certain resistance develops, as the vehicle has to move forward against the wind. Wind resistance consists of side resistance, head resistance, and tail resistance, but its exact magnitude depends upon the size and shape of the vehicle, its speed, and wind direction as well as velocity. Wind resistance depends upon the exposed area of the vehicle and the velocity and direction of the wind.

V is the velocity of wind at an angle θ. The horizontal component of wind, V cosθ, opposes the movement of the train. Wind normally exerts maximum pressure when it acts at an angle of 60° to the direction of the movement of the train.

Wind resistance can be obtained by the following formula:

$R3 = = 0.0000006WV^2$ where R3 is the wind resistance in tonnes, V is the velocity of the train in km/h, and W is the weight of the train in tonnes

Resistance Due to Gradient

When a train moves on a rising gradient, it requires extra effort in order to move against gravity

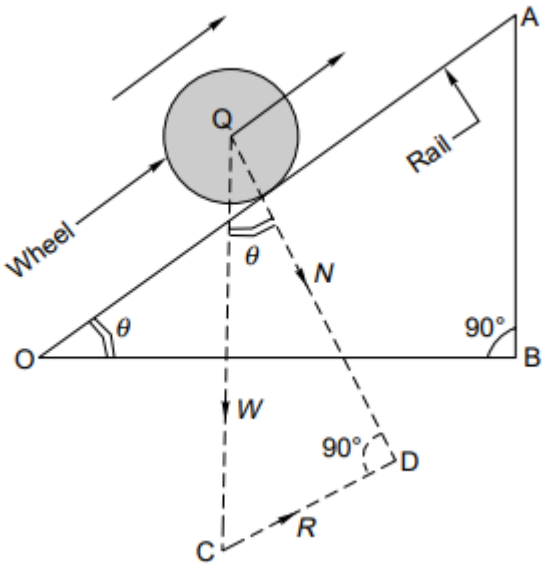

Fig. 17 Resistance due to gradient

R = % slope x W/100

Resistance Due to Curvature

When a train negotiates a horizontal curve, extra effort is required to overcome the resistance offered by the curvature of the track. Curve resistance is caused basically because of the following reasons.

(a) The vehicle cannot adapt itself to a curved track because of its rigid wheel base. This is why the frame takes up a tangential position as vehicle tries to move in a longitudinal direction along the curve as shown in Fig. On account of this, the flange of the outer wheel of the leading axle rubs against the inner face of the outer rail, giving rise to resistance to the movement of the train

(b) Curve resistance can sometimes be the result of longitudinal slip, which causes the forward motion of the wheels on a curved track. The outer wheel flange of the trailing axle remains clear and tends to derail. The position worsens further if the wheel base is long and the curve is sharp.

(c) Curve resistance is caused when a transverse slip occurs, which increases the friction between the wheel flanges and the rails.

(d) Poor track maintenance, particularly bad alignment, worn out rails, and improper levels, also increase resistance.

(e) Inadequate superelevation increases the pressure on the outer rail and, similarly, excess superelevation puts greater pressure on the inner rails, and this also contributes to an increase in resistance

Curve resistance for BG = 0.0004WD

Curve resistance for MG = 0.0003WD

Curve resistance for NG = 0.0002WD

Resistance Due to Starting and Accelerating

Trains face these resistances at stations when they start, accelerate, and decelerate. The values of these resistances are as follows:

Resistance on starting, R6 = 0.15W1 + 0.005W2

Resistance due to acceleration, R7 = 0.028aW where W1 is the weight of the locomotive in tonnes, W2 is the weight of the vehicles in tonnes, W is the total weight of the locomotive and vehicle in tonnes, i.e. W1 + W2, and a is the acceleration, which can be calculated by finding the increase in velocity per unit time, i.e., (V2 – V1)/t, where V2 is the final velocity, V1 is the initial velocity, and t is the time taken.

Hauling Power of a Locomotive

The hauling power of a locomotive depends upon the weight exerted on the driving wheels and the friction between the driving wheel and the rail. The coefficient of friction depends upon the speed of the locomotive and the condition of the rail surface. The higher the speed of the locomotive, the lower the coefficient of friction, which is about 0.1 for high speeds and 0.2 for low speeds. The condition of the rail surface, whether wet or dry, smooth or rough, etc., also plays an important role in deciding the value of the coefficient of function. If the surface is very smooth, the coefficient of friction will be very low.

Hauling power = number of pairs of driving wheels × weight exerted on the driving wheels × coefficient of friction

Thus, for a locomotive with three pairs of driving wheels, an axle load of 20 t, and a coefficient of friction equal to 0.2, the hauling power will be equal to 3 × 20 × 0.2 t, i.e., 12 t.

Signaling and Interlocking

Objectives of Signaling

The objectives of signaling are as follows.

(a) To regulate the movement of trains so that they run safely at maximum permissible speeds.

(b) To maintain a safe distance between trains that are running on the same line in the same direction.

(c) To ensure the safety of two or more trains that have to cross or approach each other.

(d) To provide facilities for safe and efficient shunting.

(e) To regulate the arrival and departure of trains from the station yard.

(f) To guide the trains to run at restricted speeds during the maintenance and repair of

tracks.

(g) To ensure the safety of the train when it comes in contact with road traffic at level crossings.

Classification of Signals

Characteristics	*Basis of classification*	*Examples*
Operational	Communication of message in audible or visual form	Audible: Detonators Visual: Hand signals, fixed signals, etc.
Functional	Signalling the driver to stop, move cautiously, proceed, or carry out shunting operations	Stop signals, shunt signals, speed indicators
Locational	Reception or departure signals	Outer, home, starter, and advanced starter signals
Special characteristics	Meant for special purposes	Calling-on signals, repeater signals, speed indicators, etc.

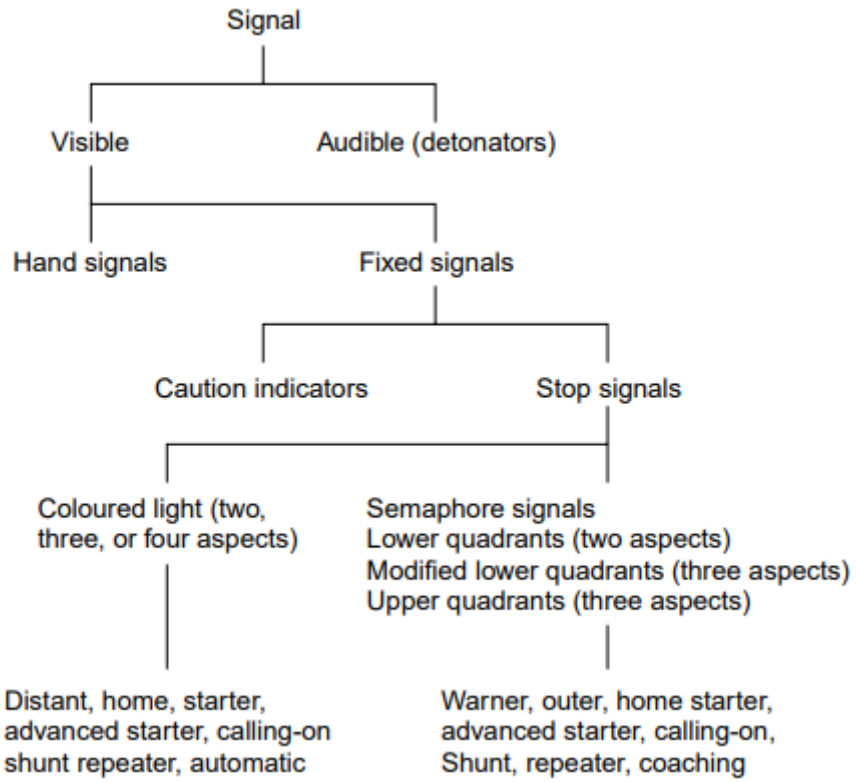

Fig.18 Classification of signals

Audible Signals

Audible signals such as detonators and fog signals are used in cloudy and foggy weather when hand or fixed signals are not visible. Their sound can immediately attract the attention of drivers. Detonators contain explosive material and are fixed to the rail by

means of clips. In thick foggy weather, detonators are kept about 90 m ahead of a signal to indicate the presence of the signal to the drivers. Once the train passes over the detonators thereby causing them to explode, the driver becomes alert and keeps a lookout for the signal so that he/she can take the requisite action

Visible Signals

These signals are visible and draw the attention of the drivers because of their strategic positions. **Hand signals**

These signals are in the form of flags (red or green) fixed to wooden handles that are held by railway personnel assigned this particular duty. If the flags are not available, signaling may be done using bare arms during the day. In the night, hand lamps with movable green and red slides are used for signaling purposes.

Fixed signal

These are firmly fixed on the ground by the side of the track and can be further subdivided into caution indicators and stop signals.

Caution indicators

These are fixed signals provided for communicating to the driver that the track ahead is not fit for the running the train at normal speed. These signals are used when engineering works are underway and are shifted from one place to another depending upon requirement.

Stop signals

These are fixed signals that normally do not change their position. They inform the drivers about the condition of the railway line lying ahead. The stop signals normally used on railways are semaphore signals, coloured light signals, and other such signals as explained in subsequent sections.

Fixed Signals

The various types of fixed signals used on railways are as follows.

Semaphore signals

A semaphore signal consists of a movable arm pivoted on a vertical post through a horizontal pin as shown in Fig.

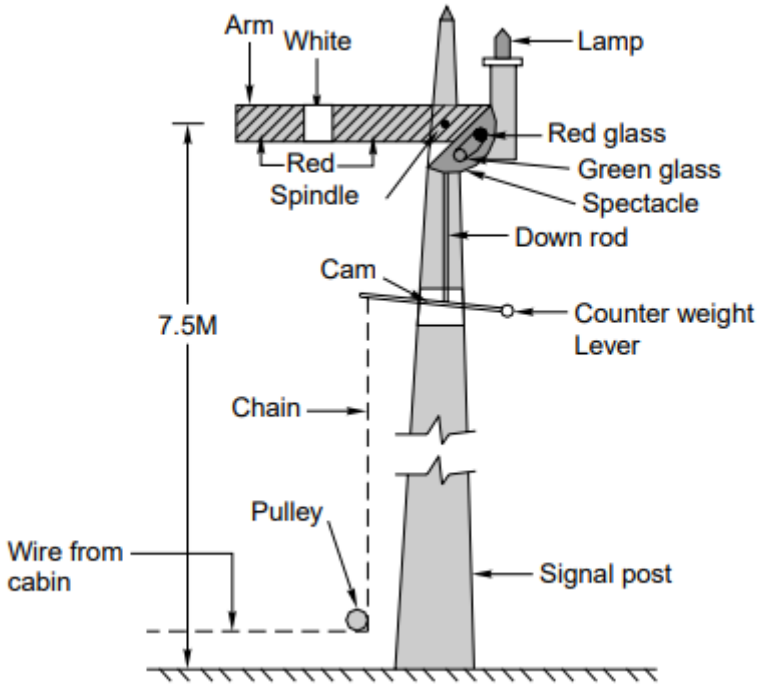

Fig. 19 Semaphore signal

The arm of the semaphore signal on the side facing the driver is painted red with a vertical white stripe. The other side of the signal is painted white with a black vertical stripe. The complete mechanical assembly of the signal consists of an arm, a pivot, a counterweight spring stop, etc., and is housed on top of a tubular or lattice post. In order for the signal to also be visible at night, a kerosene oil or electric lamp, operated through a twilight switch, is fixed to the post. A spectacle is also attached to the moving signal arm, which contains green and red coloured glasses. The red glass is positioned at the upper end and the green glass is positioned at the lower end of the spectacle so that the red light is visible to the driver when the arm is horizontal and the green light is visible when the arm is lowered. The semaphore signal can be used as a stop signal as well as a warner signal.

Permissive signal—warner or distant signal

In order to ensure that trains speed up safely, it is considered necessary that warning be given to drivers before they approach a stop signal. This advance warning is considered necessary, otherwise the drivers may confront a ‘stop signal’ when they least expect it and take abrupt action, which can lead to perilous situations. A warner or distant signal has, therefore, been developed, which is to be used ahead of a stop signal and is in the form of a permissive signal that can be passed even in most restricted conditions. In the case of a stop signal, the driver has to stop the train when it is in the ‘on’ position, but in the case of a permissive signal, the driver can pass through even when it is in the ‘on’ position. The

most restrictive aspect of a permissive or warner signal is that the driver is not supposed to stop at the signal even when it is in the 'on' position. The warner signal is similar to a stop signal except that the movable arm is given the shape of fish tail by providing a V-shaped notch at the free end; the white strip is also V-shaped.

Table 2 Position of Warner signal

Position	*Day indication for semaphore signal*	*Night indication for semaphore signal**	*Aspect*
On	Arm horizontal	Red light	Proceed with caution and be prepared to stop at the next stop
Caution	Arm inclined 45° in the upward direction	Yellow light	Proceed cautiously so as to pass the next stop signal at a restricted speed
Off	Arm inclined 90° is the upward or 45° is the downward direction	Green light	Proceed at full permissible speed, next stop signal is also green

Coloured light signals

These signals use coloured lights to indicate track conditions to the driver both during the day and the night. In order to ensure good visibility of these light signals, particularly during daytime, the light emission of an electric 12-V, 33-W lamp is passed through a combination of lenses in such a way that a parallel beam of focused light is emitted out. This light is protected by special lenses and hoods and can be distinctly seen even in the brightest sunlight. The lights are fixed on a vertical post in such a way that they are in line with the driver's eye level. The system of interlocking is so arranged that only one aspect is displayed at a time. Coloured light signals are normally used in suburban sections and sections with a high traffic density.

Calling-on signal

This consists of a small arm fixed on a home signal post below the main semaphore arm (Fig. 31.6). When the main home signal is in the horizontal (on) position and the calling-on signal is in on inclined (off) position, it indicates that the train is permitted to proceed cautiously on the line till it comes across the next stop signal. Thus the calling-on signal is meant to 'call' the train, which is waiting beyond the home signal. The calling-on signal is useful when the main signal fails, and in order to receive a train, an authority letter has

to be sent to the driver of the waiting train to instruct him/her to proceed to the station against what is indicated by the signal. In big stations and yards, the stop signals may be situated far off from the cabin and the calling-on signal expedites the quick reception of the train even the when signal is defective

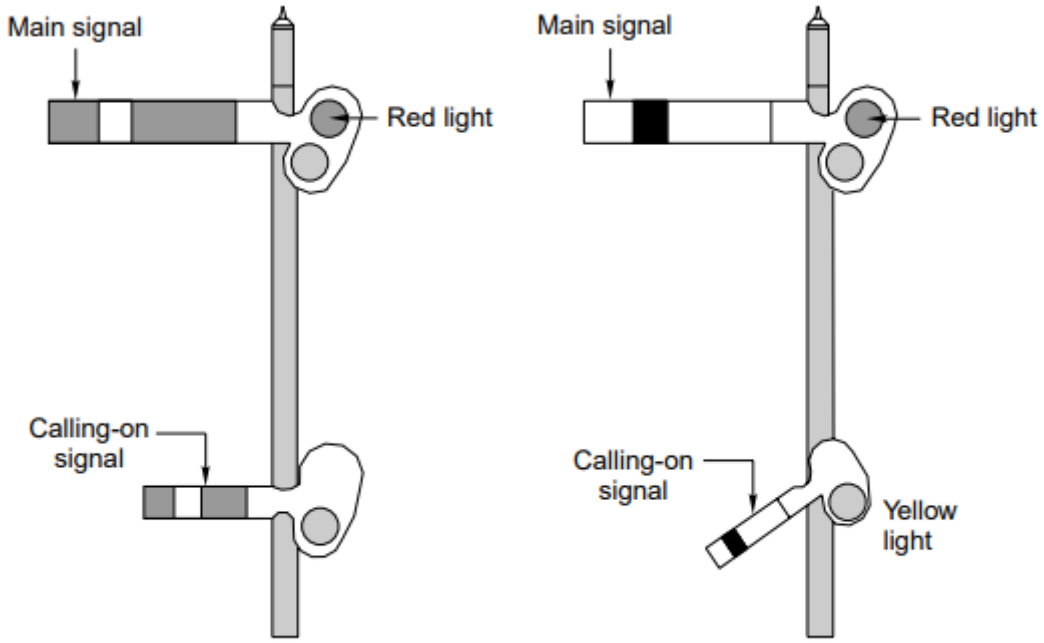

Fig. 20 Calling-on signal

Repeater signal

In cases where a signal is not visible to the driver from an adequate distance due to sharp curvature or any other reason or where the signal is not visible to the guard of the train from his position at the rear end of a platform, a repeater signal is provided at a suitable position at the rear of the main signal. A repeater signal is provided with an R marker and can be of the following types.

(a) A square-ended semaphore arm with a yellow background and a black vertical band.

(b) A coloured light repeater signal.

(c) A rotary or disc banner type signal. The ‘off’ positions of these three types of repeater signals are depicted in Fig.

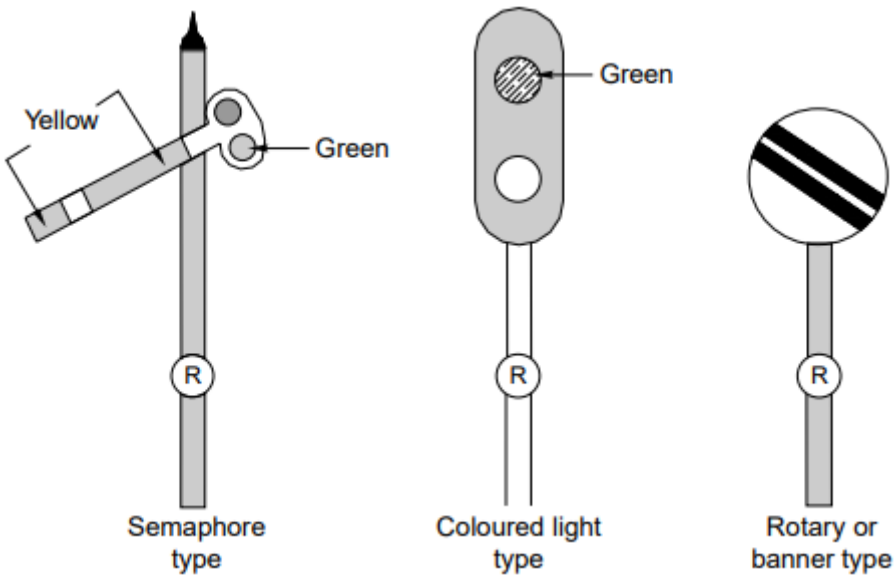

Fig. 21 Repeater signal

Shunt signals

These are miniature signals and are mostly used for regulating the shunting of vehicles in station yards. Unlike fixed signals, these are small in size and are placed on an independent post of a running signal post. In semaphore signalling areas, the shunt signals are of the disc type. The disc type of shunt signal consists of a circular disc with a red band on a white background. The disc revolves around a pivot and is provided with two holes, one for the red lamp and the other for the green lamp, for the purpose of night indication. At night, the ‘on’ position of the signal is indicated by the horizontal red band and the red light, indicating danger. During the day the red band inclined to the horizontal plane and during the night the green light indicate that the signal is ‘off’

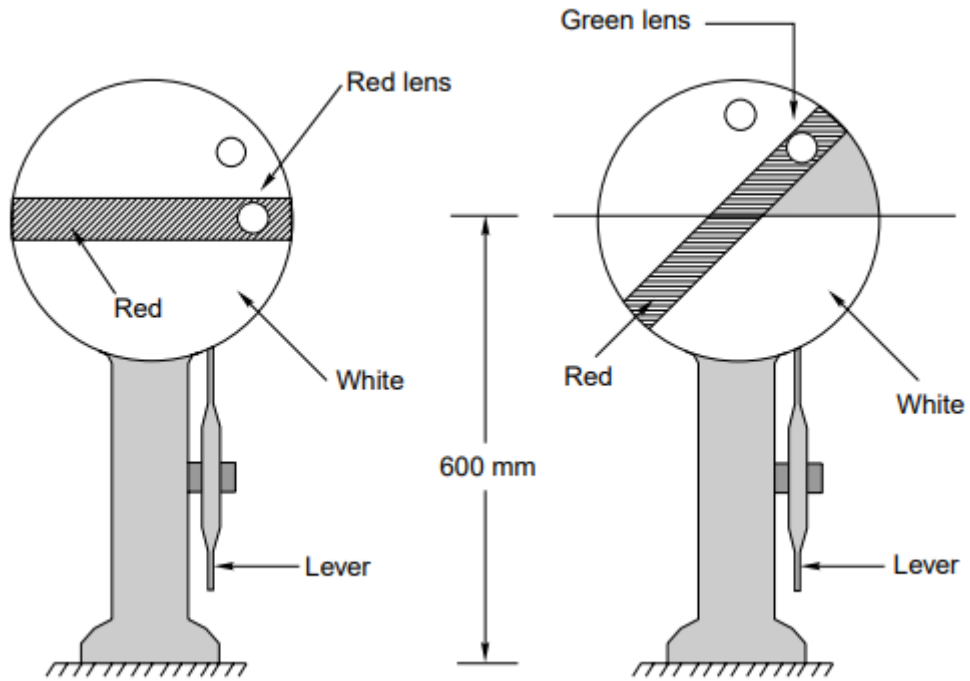

Fig. 22 Disc type of shunt signals

Caution indicators

When the track is undergoing repair, trains are required to proceed with caution at restricted speeds and may even have to stop. Caution indicators help the driver of a train to reduce the speed of (or even stop) the train at the affected portion of the track and then return it to the normal speed once that portion has been covered. The following indicators are used for this purpose.

Caution indicator

This cautions the driver to get ready to reduce the speed.

Speed indicator

The driver has to reduce the speed (or stop) at this location.

Stop indicator or stop board

The driver has to stop the train at this location.

Termination indicator

This indicates that the driver can assume normal speed and that the speed restriction zone has ended. These indicators are also called temporary fixed engineering signals and are provided in the direction of the approaching train in the case of double lines and in both directions in the case of single lines

Stop Signals

The various types of signals with reference to their location on a station are discussed in detail below.

Outer signal

This is the first stop signal at a station, which indicates the entry of a train from a block section into the station limits. This signal is provided at an adequate distance beyond the station limits so that the line is not obstructed once the permission to approach has been given. It is provided at a distance of about 580 m from the home signal. The signal has one arm but has a warner signal nearly 2 m below on the same post. When the outer signal is in the 'on' (or stop) position, it indicates that the driver must bring the train to a stop at a distance of about 9 m from the signal and then proceed with caution towards the home signal. If the outer signal is in the 'off' (or proceed) position, it indicates that the driver does not need to reduce the speed of the train if the home signal is also in the 'off' (or proceed) position, which is indicated by the 'off' position of the warner. As the outer signal controls the reception of trains, it comes under the category of reception signals. **Home signal**

After the outer signal, the next stop signal towards the station side is a home signal. It is provided right at the entrance of the station for the protection of the station limits. The signal is provided about 190 m short of the points and crossings. The arms provided on a home signal are generally as many as the number of reception lines in the station yard. When a home signal is in the 'on' (or stop) position it indicates that the train must come to a halt short of the signal. In the 'off' (or proceed) position, it indicates that the particular line is free and the train is permitted to enter cautiously. The home signal also comes in the category of reception signals.

Routing signal

The various signals fixed on the same vertical post for both main and branch lines are known as routing signals. These signals indicate the route that has been earmarked for the reception of the train. Generally the signal for the main line is kept at a higher level than that for the loop line. It is necessary for the driver of a train approaching a reception signal to know the line on which his or her train is likely to be received so that he or she can regulate the speed of the train accordingly. In case the train is being received on the loop line, the speed has to be restricted to about 15 km/h, whereas if the reception is on the main line a higher speed is permissible. The various positions of the routing signal for a station with an outer signal, a home signal, and a warner signal that is provided below the outer

signal are shown in Fig.

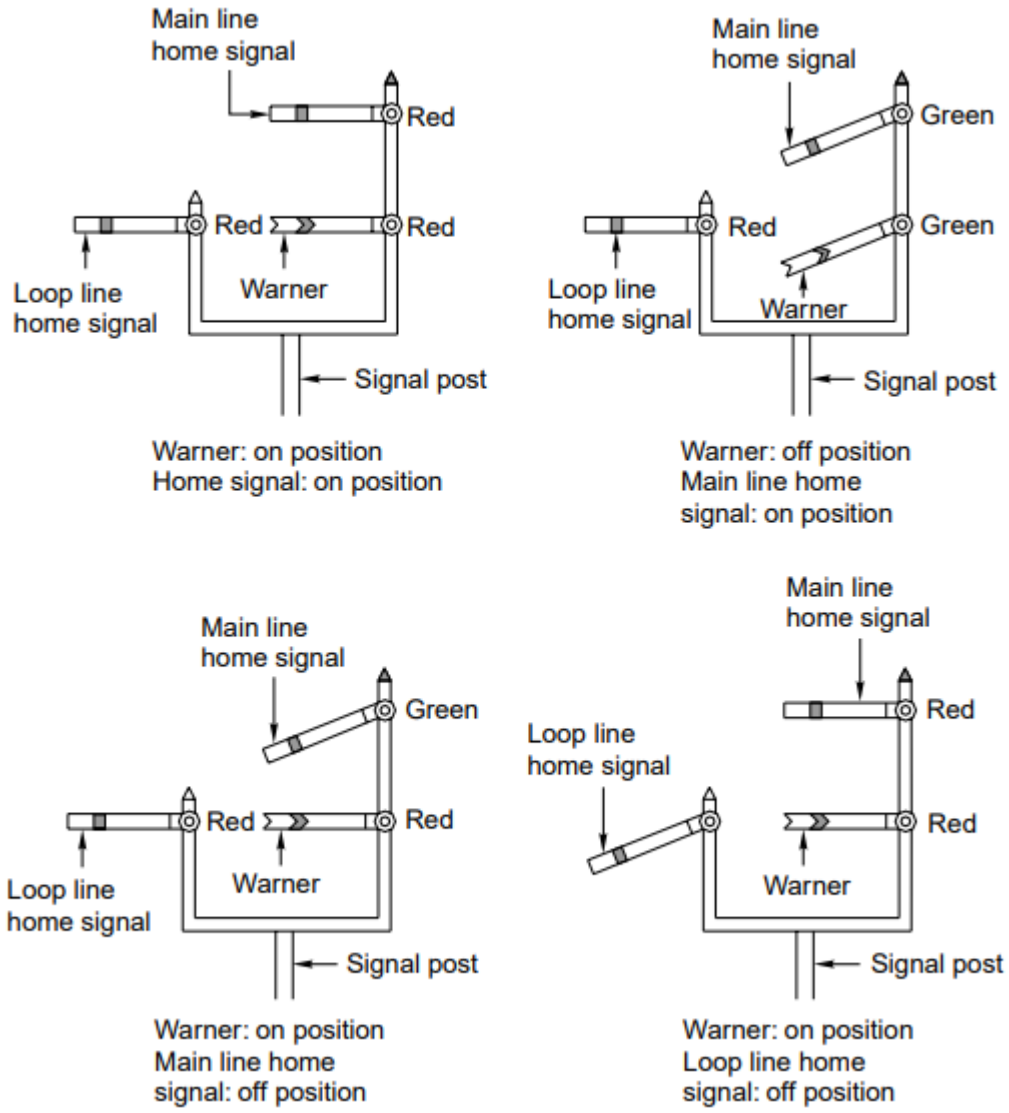

Fig. 23 Routing signals with outer, home, and warner signals

Starter signal

The starter signal is a stop signal and marks the limit up to which a particular line can be occupied without infringing on other lines. A separate starter signal is provided for each line. The starter signal controls the movement of the train when it departs from the station. The train leaves the station only when the starter signal is in the 'off' (or proceed) position. As this signal controls the departure of a train, it comes under the category of departure signals.

Advanced starter signal

This is the last stop signal provided for the departure of trains from a station. The signal is provided about 180 m beyond the outermost points or switches and marks the end of the

station limits. A block section lies between the advanced starter signal of one station and the outer signal of the next station. No train can leave the station limits until and unless the advance starter is lowered.

What is Interlocking?

- Interlocking is a device or a system meant to ensure the safety of trains.
- With the increase in the number of points and the signals and introduction of high speeds, it has become necessary to eliminate human error, which would otherwise lead to massive losses of life and property.
- The points and signals are set in such a way that the cabin man cannot lower the Signal for the reception of a train unless the corresponding points have been set and locked.
- The Signal is thus interlocked with the points in a way that no conflicting movement is possible, and the safety of trains is ensured.
- Interlocking can, therefore, be defined as an arrangement of signals, points, and other apparatus so interconnected by means of mechanical or electrical interlocking that they can be operated in a predetermined sequence to ensure that there is no conflicting movement of signals and points and trains run safely.
- The Signal and interlocking system is so designed that the failure of any equipment results in the turning on of the Signal, thus ensuring train safety.

Principles of Interlocking

The basic principles of interlocking are as follows: -

1. It shall not be possible to take "off" conflicting signals.
2. It shall be possible to take the "off" Signal for a running line only when:

- All points on the running line are correctly set, and facing points locked.
- All points, giving access to the running line from the sidings and goods lines, are set against the running line.
- Level crossing gates, if included or controlled by interlocking, are closed and locked against the road traffic.
- A signal lever, when operated, must lock or back lock as necessary the levers operating the points and gate locks referred to above.

- Once the Signal is taken off, it shall not be possible to alter the points, unlock the gate lever, etc., until all signals are taken off and have been put back.

1. When all signals are in the "On" position, all points which would be locked by taking 'off' such signals must be free for shunting purposes/testing, etc.
2. It must be impossible to take "off" a Warner Signal until all the relevant stop signals in advance have first been taken "off," and when "off," it must back lock all such signals.

Types of Interlocking

1. Mechanical Interlocking.
2. Electro Mechanical Interlocking.
3. Panel Interlocking (Relay)
4. Route Relay Interlocking.
5. Solid State Interlocking(SSI)

Mechanical Interlocking

- In mechanical signaling, since the functions are operated by levers, the relationship that should exist between the functions can be transferred to exist between the levers.
- To ensure that the Signal can be taken 'OFF' only after the point is correctly set, we can arrange the Interlocking between the signal lever and point lever to be such that the signal lever can be reversed only after the point lever is in the correct position, viz. 'Normal' or 'Reverse,' as the case may be.
- As the size of yards & train movements increased, the size of lever frames also increased.
- These lever frames not only increased in size occupying more space, but also required intensive maintenance.

Electro Mechanical Interlocking

- Electromechanical interlocking is a more modern approach that combines mechanical and electrical components to control train movements.
- It incorporates electrical circuits, relays, and logic units alongside the mechanical linkages. The electrical components enable more precise and rapid control of switches and signals, allowing for greater flexibility in handling complex track configurations.

- These use computer-based control systems, which offer enhanced functionality, diagnostics, and remote monitoring capabilities.

Panel Interlocking

- With the advent of Electro-mechanical relays, lever frames gave way to relay interlocking-based installations.
- This development resulted in relatively faster operation, fail-safe operation, and reduced size of buildings required for housing interlocking installations.
- With further increase in traffic and expansion of the railway network, panel Interlocking installations were commissioned.

Route Relay Interlocking

- Route Relay interlocking is the same as Panel Interlocking, with Electro-Mechanical Relays doing the Interlocking, except that it can be employed for big yards.
- The Interlocking is done between one route and another route. Another important feature in terms of the operating point of view is that the SM has to only press two buttons, the Signal button & Route Button (entry-exit system).
- Computer-based Interlocking uses thousands of Electro-mechanical relays requiring complex wiring and Interconnections. The wiring diagrams for such installations run into hundreds of sheets. Individual relays, wiring, and interconnections, along with thousands of shouldered joints, are required to be physically examined and certified. This exercise requires traffic blocks of long durations and large manpower to manage the traffic during blocks.
- Even for small yard re-modeling, like the addition of a loop line, all the above activities are required to be redone. Therefore, the advantages of relay-based interlocking installations are being nullified.
- The SSI system occupies considerably less space, consumes less power, is more reliable, and is easy to install and maintain. Also, initial commissioning & changes due to yard re-modeling can be carried out in negligible time, requiring skeleton manpower for traffic management during the blocks.
- Unlike PI or RRI, Microprocessors (ICs) are doing the Interlocking based on predetermined logic circuits.

Indirect and Direct Interlocking

(a) Indirect Interlocking means that the points are set and locked from one place and the signals are operated from another place and another lever frame; the Interlocking is effected by means of keys carried from one place to the other.

(b) Direct Interlocking means that all levers, viz. the point, the point locks and the signal levers are concentrated in one lever frame and worked therefrom; the Interlocking is effected by means of rigid connections between levers without the use of Keys.

Solid State Interlocking (SSI):

Computer based interlocking uses thousands of Electro-mechanical relays requiring complex wiring and Inter-connections. The wiring diagrams for such installations run into hundreds of sheets. Individual relays, wiring and interconnections along with thousands of shouldered joints are required to be physically examined and certified. This exercise requires traffic blocks of long durations and large manpower to manage the traffic during blocks. Even for small yard re-modelling like addition of a loop line, all the above activities are required to be redone. Therefore, the advantages of relay based interlocking installations are being nullified. The SSI system occupies considerably less space, consumes less power, is more reliable and is easy to install and maintain. Also, initial commissioning & changes due to yard re-modeling can be carried out in negligible time requiring skeleton manpower for traffic management during the blocks. Unlike PI or RRI, Microprocessors (IC'S) are doing the Interlocking based on pre-determined logic circuits.

Advantages of SSI:-

- Increase in section capacity.
- Faster operation.
- User friendly operation.
- Fail safe technique
- Multiple mode operation.

Significance of SSI for operating staff:

- Reduces man power
- Centralised operation
- Multiple mode of operation
- Control cum indication panel
- Video display unit (P.C)
- CTC (Centralised Traffic Control)—permits remote control
- Significant reduction in traffic block time
- Easier & simple operation

Module III

Airport Site Selection Criteria

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:

Airport Site Selection Criteria

1. Atmospheric & Meteorological Conditions
2. Availability of land for Expansion.
3. Availability of utilities
4. Development of the Surrounding Area
5. Economy of Construction
6. Ground Accessibility
7. Presence of other Airports
8. Regional Plan
9. Soil Characteristics
10. Topography
11. Use of airport

Atmospheric & Meteorological Conditions

- The presence of Fog, Haze & Smoke reduces the visibility & the Poor visibility lowers the traffic capacity of an Aircraft.
- The fog has a tendency to settle into Areas where there is Little Wind.
- The lack of wind is caused by the Topographical Features of the Surrounding locality.
- In a similar way, the smoke & Haze are present at Sites very Near to the large industrial Areas.

Availability of Land for Expansion

- The field of Aviation is expanding day by day. It is Therefore Necessary to acquire land in advance for future expanding of Airport.
- As the volume of Traffic increases, it will be necessary to lengthen the runways to provide additional support facilities & to expand the terminal facilities.

Availability of utilities

- An airport, especially a large one, has to be provided with utilities like Water electric power, Telephone, sewer etc.

- For electric power, Most of the Major airports provide their own generating plants to be used in emergencies in the event when a commercial Source fails.

Development of Surrounding Area

- The study of the type of development of the Surrounding area is very important because the airport activities, particularly from the Standpoint of Noise, are often quite objectionable to the Neighbours of the Airport.
- The proximity of Airport site to the residential areas, schools & hospitals should be avoided whenever possible. Suitable zoning regulations should be imposed to control the use of the land adjacent to the airport so that conflicts in future are avoided.

Economy of construction

- It is clear that if alternative sites are available & equally well Suited, the site which is more economical to construct should be given preference.
- The sites having water logged areas or reclaimed lands are very costly to develop than those of Natural Ground.
- The uneven terrain requires much more grading than flat or even terrain.
- The availability of local construction materials may also have a significant impact on the cost of the Project.

Presence of other Airports

- The airports should be located at a sufficient distance Apart.
- This is necessary to prevent the aircrafts which are Manoeuvring for a landing at one airport from interfering with the movements of the Aircrafts at other Aircrafts.

Soil characteristic

• The airport site with the favourable soil characteristic is desirable because it reduces the cost of grading & drainage to a considerable extent.

• The area should as far as possible be self-drained.

Topography

• The topographical features like ground contours, trees, streams, etc. should be avoided while selecting the site for an Airport.

• A raised ground like a hill top is usually considered to be an ideal site for an Airport because of the following facts.

• It grants better visibility due to less fog

• It permits easy Natural drainage

• The Approach & turning zones are less obstructed

• There is Natural drainage.

Use of Airport

- The airport site is decided also by the use of Airport, i.e Civil or military.
- In case of an emergency like War, the civilian Airports are taken over by Military.
- It is therefore necessary to see that the Airport site Grants Natural Protection from Possible Air Attacks during War.

Aircraft characteristics

- Type of propulsion
- Size of aircraft
- Min turning radius
- Min circling radius
- Speed of aircraft
- Aircraft weight and wheel configuration
- Jet blast
- Fuel spillage
- Noise

Type of propulsion

Table 3 Type of propulsion

Engine	Speed limit kmph
Piston	250-750
Ram jet	1280-2400
Rocket	4600

Size of Aircraft

- Wing span
- Fuselage length
- Height
- Distance between main gears
- Wheelbase
- Trail widt
- **Wing span decides**

Width of taxi way

- Clearance between two parallel traffic ways
- Size of apron and hanger
- Width of hanger gate

Length of aircraft decides

- Widening of taxi way on curves
- Sizes of apron and hanger
- Height of aircraft or empennage height
- It decides the height of hanger gate
- The gear tread and wheel base
- Min turning radius of the aircraft.

Min turning radius

- A line is drawn through the axis of nose gear when it is at its max angle of rotation.
- Theoretically max angle of rotation is 900
- It will causes the skidding because it is producing excessive wear.
- Max angle of nose gear limited 50° to 60° for turbo jet.

Min circling radius

- Type of aircraft
- Traffic volume
- Weather conditions
- The diff radii for diff types of aircraft
- Small gear aviation aircraft under UFR condition=1.6 km
- Bigger aircraft, say two piston engine under VFR condition =3.2 km
- Piston engine aircraft under IFR =13 km
- Jet engine aircraft under IFR =80 km

Speed of Aircraft

It is split into two ways

- Cruising speed or ground speed: It is the speed of air craft with respect to the ground when the aircraft flying in air at its max speed.
- Air speed: It is the speed of aircraft relative to the wind.

Weight of Aircraft & wheel configuration

- Wt of Aircraft directly influence the length of runway and structural requirements, i.e. the thickness of runway, taxiway, apron and hangers.

Jet blast

- High velocity Aircraft it will eject the hot exhaust gases.
- The velocity of jet blast may be high as 300kmph
- Due to this passenger may feel inconvenience.
- To avoid this problems several jet blast deflectors are available.

Fuel spillage

- It is very diff to avoid the fuel spillages at loading aprons and hanger.
- Bitumen pavement are affected by the fuel spillage.
- But it should bring within min limit.
- So that constant supervision is required at fuel inlets, engines and main landing gear.

Noise

- Noise generated by Aircraft create problem.
- Layout and capacity depend on it.
- It should be min as per as possible.

Various surface of an airport

Primary Surface: Aligned (longitudinally) with each runway and extends 200 ft. from each runway end

Horizontal Surface: Horizontal plane 150 ft. above the established airport elevation. Constructed by swinging arcs around the end of the primary surface

Conical Surface: 20:1 slope surface extending beyond the horizontal surface

Transitional Surface: Constructed to join approach and horizontal or approach and transitional surfaces

Approach Surface: Longitudinally centered with the runway and extends beyond the primary surface

Wind rose diagram

A wind rose is a graphical tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. Historically, wind roses were predecessors of the compass rose (found on maps), as there was no differentiation between a cardinal direction and the wind, which blew from such a direction.

- Using a polar coordinate system of gridding, the frequency of winds over a long time period is plotted by wind direction, with color bands showing wind ranges.
- The directions of rose with the longest spoke show the wind direction with the greatest frequency.

Uses of wind rose:

- Presented in a circular format, the modern wind rose shows the frequency of winds blowing from particular directions over a specified period.
- The length of each "spoke" around the circle is related to the frequency that the wind blows from a particular direction per unit time.
- Each concentric circle represents a different frequency, emanating from zero at the center to increasing frequencies at the outer circles.
- A wind rose plot may contain additional information, in that each spoke is broken down into color- coded bands that show wind speed ranges.
- Wind roses typically use 16 cardinal directions, such as north (N), NNE, NE, etc although they may be subdivided into as many as 32 directions.
- In terms of angular measurement in degrees, North corresponds to 0°/360°, east to 90°, South to 180° and West to 270°.
- Compiling a wind rose is one of the preliminary steps taken in constructing airport runways, as aircraft typically perform their best take offs and landings pointing into the wind.

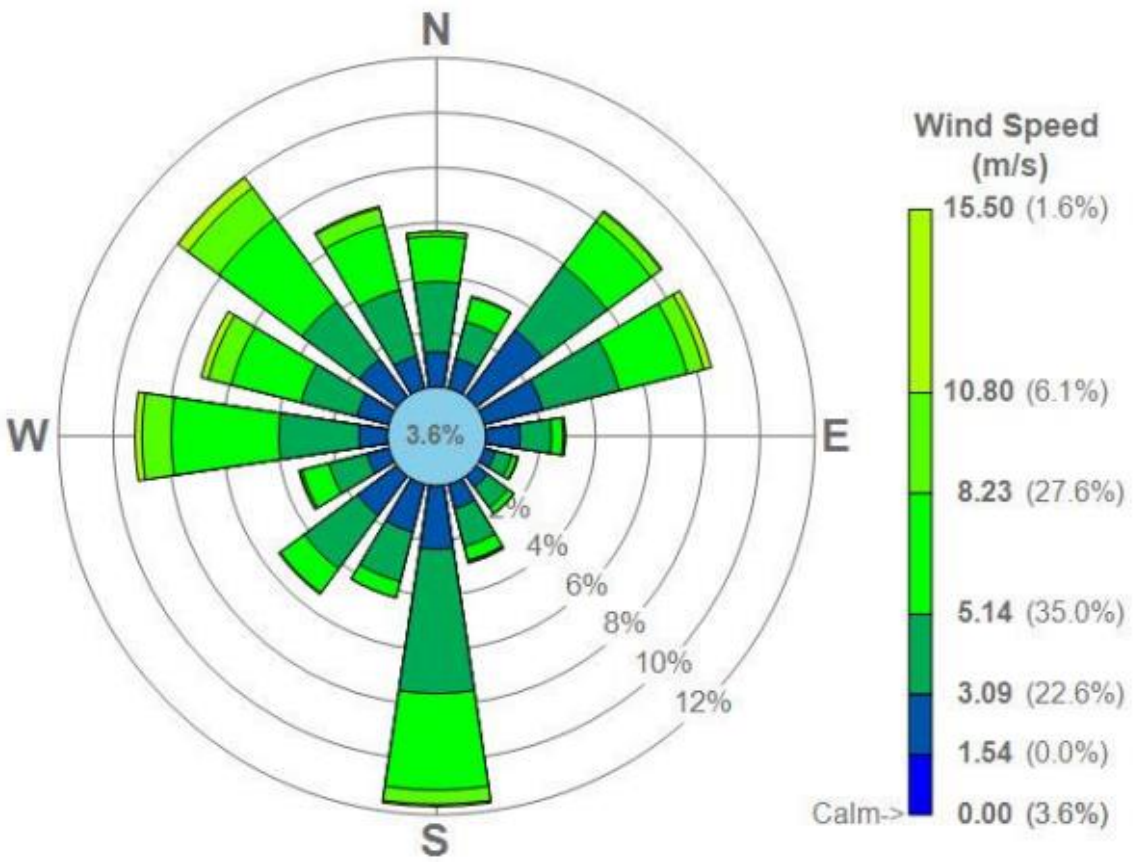

Fig. 24 Wind rose diagram

Geometric design of runway

- Length
- Longitudinal and Effective gradient
- Safety Area
- Sight Distance
- Transverse Gradient
- Width

Length of Runway

The Basic runway length is given by ICAO in accordance with the classification of airports. The actual runway length is computed after applying corrections in length for: –

- Elevation
- Temperature,
- and Gradient

Longitudinal and Effective gradient

The longitudinal gradient increases the runway length Fuel consumption of aircraft increases on uphill slope climbing during take-off.

Safety Area

It includes runway, shoulders on either side of runway, and additional length The shoulders are generally unpaved They are only used in case of emergency They are generally turfed or made of stabilized soil Shoulders provide a sense of openness and vastness to pilot.The length of safety area should extend by 60m on either side beyond runway ends The total length of safety area is = Runway Length +120

Stop way

A stop way is an area beyond the runway to decelerating an aircraft in case of an aborted takeoff. It must be at least as wide as the runway and must be capable of supporting an airplane without causing structural damage to it.

Clearway

A clearway is a defined area connected to the end of a runway It increases the allowable airplane operating takeoff weight without increasing runway length.

Runway:

Design Criteria

It should be designed keeping in view the characteristics of critical aircraft.

The major design guidelines: Length, width, and orientation (direction),

Configuration (multiple runways),

Slope (Longitudinal and cross)

Pavement thickness of runways

Immediate airfield area surrounding the runways obstructions

Runway Lights

Runway End Identifier Lights (REILs): A pair of white flashing lights, one on each side of the approach end of the runway that help identify the runway from taxiways at night. Runway Edge Light Systems (HIRL/MIRL/LIRL): The runway edge lights are steady white lights on the edges of the runways. On instrument runways, the white lights change to yellow during last 2,000 feet, or half the runway length, whichever is less, and then they turn red as the aircraft reaches the end of the runway. They can be high—intensity.

Runway Centreline Lighting System (RCLS) - On some precision runways, a runway centreline light system is installed, with white lights spaced at 50-ft intervals on the centreline

of the runway. With 3,000 feet remaining, the white lights change to alternating white and red, and then all red during last 1,000 feet.

Touchdown Zone Lights (TDZL) - Touchdown zone lights are steady white lights placed in two rows next to the centreline, starting at 100 feet and extending to the midpoint of the runway, or 3,000 feet beyond the threshold, whichever is less.

Land and Hold Short Lights - When land and hold short operations (LAHSO) are in effect, flashing white lights may be seen across the runway at the hold short line.

Other runway lighting may include Runway Status Lights (RWSL), which includes Runway Entrance Lights (RELs), the Take-off Hold Light Array (THL), Runway Intersection Lights (RILs), and the Final Approach Runway Occupancy Signal (FAROS). These lights work in conjunction with surveillance systems and are fully automated. They assist in informing pilots and ground vehicle operators when it's safe to enter or cross a runway

Taxiway

Taxiways are defined as paths on the airfield surface for the taxing of the aircraft and are intended to provide linkage between one part of the airfield and another part of the airfield. What it wants to say is that we are trying to provide the connectivity for those aircrafts, which are reaching or arriving on any of the airport, so that they can taxi on this particular lane away from the active runway strip on which the continuous movements are going on and in that sense it provides a connectivity between the different locations or different parts of any airport and all those such connectivity's are termed as taxiways.

Taxiway is the paved way rigid or flexible which connects runway with loading apron or service and maintenance hangers or with another runway. They are used for the movement of aircraft on the airfields for various purposes such as exit or landing, exit for take-off etc. The speed of aircraft on taxiway is less than that during taking off or landing speed.

The taxiway should be laid on such a manner to provide the shortest possible path and to prevent the interference of landed aircraft taxying towards loading apron and the taxiing aircraft running towards the runway. The intersection of runway and taxiway should be given proper attention because during turning operation, this part comes under intense loading. If it is weaker than the aero plane may fell down from taxiway. Its longitudinal grade should not be greater than 3% while its transverse gradient should not be less than 0.5%. It is also provided with a shoulder of 7.5m width paved with bituminous surfacing. The taxiway should be visible from a distance of 300m to a pilot at 3m height from the ground.

Function of Taxiways

They connect runways with other areas, like terminal building, cargo, and parking areas. Taxiways gives access for aircraft to and from the runways.

Taxiway Lights

Taxiway Edge Lights: Taxiway edge lights are blue in color and line the taxiways. Airports often have green taxiway centreline lights, as well.

Clearance Bar Lights - Set inside the taxiway, clearance bar lights are steady yellow and are meant to increase the visibility of a hold line or a taxiway intersection at night.

Stop Bar Lights - Only installed at select airports, stop bar lights are meant to reinforce an ATC clearance to cross or enter a runway in low visibility situations (low IMC). They're in-pavement lights that are steady red and extend across the taxiway at a hold short line. Once a pilot is cleared onto the runway, the stop bar lights will be turned off.

Runway Guard Lights - A pair of two steady yellow lights that are positioned at each side of the taxiway at the hold short line, the runway guard lights are meant to draw attention to the hold short line - the area where a taxiway meets the runway.

Types of taxiways

Parallel taxiway

Provided parallel to an adjacent runway, It facilitates aircrafts to reach the apron area from runway after landing and from apron area to runway for take-off.

Entrance taxiway

Located near the runway threshold. It facilitates entry of an aircraft to runway for take-off operation.

Exit taxiways

Located at various points along the runway to allow landing aircraft to efficiently exit the runway after landing.

Bypass taxiways

Provided to give way to aircraft, Located at areas of congestion at busy airports.

Taxiways:

Design Criteria

- Provide each runway with a parallel taxiway
- Design taxiways of optimum length Provide bypass capability or multiple accesses to runway ends
- Minimize crossing runways

- Provide large curves and fillet radii for easier manoeuvring of aircrafts
- Provide airport traffic control tower line-of-sight

Holding apron

- Apron is the area of an airport where aircraft are parked, unloaded or loaded, refuelled, or boarded.
- Although the use of the apron is covered by regulations, it is more accessible to users than the runway or taxiway. However, the apron is not usually open to the general public and a license may be required to gain access.
- It is located close to the terminal building or hangars.
- The size of apron depends on: a) Type of aircraft. b) Number of Gate Positions. c) Aircraft Parking System.

Types of Aprons:-

Terminal Aprons and Ramps

- Aircraft parking positions, also called aircraft gates or aircraft stands, on the terminal apron or ramp are sized for the geometric properties of a given design aircraft, including wingspan, fuselage length and turning radii.
- Both the FAA and ICAO recommend minimum clearances between any part of an aircraft and other aircraft or structures in the apron area.

Holding Aprons

- Holding aprons, holding pads, run-up pads, or holding bays as they are sometimes called, are placed adjacent to the ends of runways.
- The areas are used as storage areas for aircraft prior to take off.
- They are designed so that one aircraft can bypass another whenever this is necessary

Terminal Building

- The purpose of airport building is to provide shelter and space for the various surface activities related to the air transportation.
- Terminal building usually refers to a building mainly, used for passenger, airline and administration facilities
- planned for the maximum efficiency, convenience and economy

Visual aids:-

- Visual aids are installed at the airport to achieve the following purposed:
- To avoid accidents during landing of the aircraft.
- To convey to the pilot the ground to air visual information required during landing

- To direct the pilot to make the landing of the aircraft to the landing area only.
- To enable the pilot to locate and identify the particular feature specified by the making.
- To provide safety to the persons and properties.
- To maintain an orderly flow of aircraft without any congestion.
- To satisfy the visual requirements for take-off and taxiing.

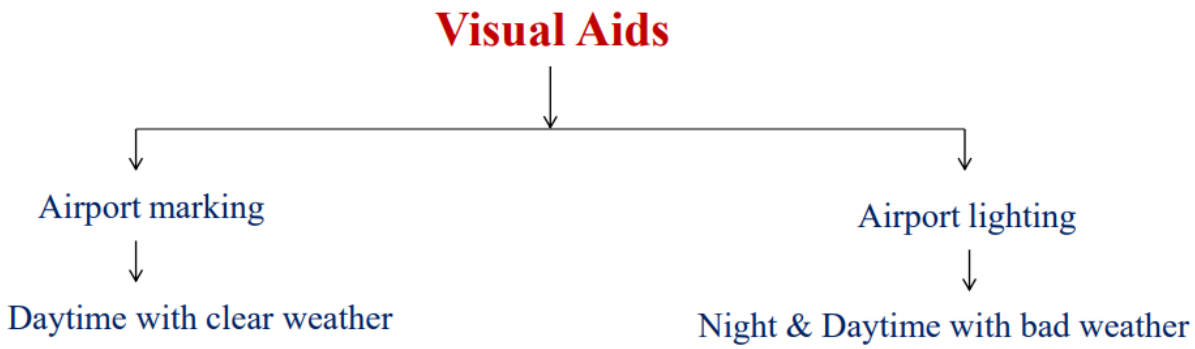

Fig. 25 Visual aids

Airport Marking

- For assisting the pilots in guiding the aircraft on the runways and taxiways.
- The pavements are marked with lines and numbers.
- These airport marking are of benefits to the pilot.

The airport markings are divided into the following groups:

- Runway Marking
- Taxiway Marking
- Runway and Taxiway shoulder marking
- Apron Marking
- Wind direction indicator
- Landing direction indicator

Runway Markings:-

Following markings are made on the runways

- Runway centre-line marking
- Runway edge stripes
- Runway numbering
- Touch down zone marking
- Threshold marking
- Displaced threshold marking

Runway Centre Line Marking:-

The centre line of the runway is represented by the broken strip running along the entire length of the runway as shown in figure. Its width is 90 cm.

Runway Edge Stripes:-

The runway edge stripes are normally marked. But when the runway width exceeds 45 m, the side stripes in the form of long continuous lines 90 cm wide may be marked near the edges

Touch Down Zone Marking

The runway touch down zone or landing zone is indicated by a series of stripes arranged symmetrically about the centre-line with their number decreasing gradually in the direction of landing.

Runway Numbering

The end of each runway is marked with a number which indicates the magnetic azimuth, i.e. the angle measured in the clockwise direction from the north of the runway in the direction of the landing. Thus, the east end of the east-west runway would be marked 27 (for 270 ° and the west end 9 (for 90°).

Threshold Marking:-

- The runway threshold is indicated by a series of parallel lines starting from a distance of 6 m from the runway end.
- The threshold markings are in the form of stripes 3.6 m wide spaced at 0.9 m clear and placed symmetrically on either side of the runway centre-line.

Displaced Threshold Marking:-

- At some airports, it is desirable to displace the runway threshold on a permanent basis.
- A displaced threshold is one which has been moved a certain distance from the end of the runway.

Taxiway Marking

- A single continuous 15 cm yellow stripe is used to mark the centre line of the taxiway.
- At the intersections of the taxiways with the runway ends, the centre line of the taxiway is terminated at the edge of the runway.
- All other intersections of the taxiways with runways, the centre line of the taxiway is extended to the centre line of the runway.
- A holding line marking is painted at all the intersections of the paved taxiways with runways.

- At the taxiway intersection, the centre line markings of the taxiway continue through the intersection area.

Shoulder Marking

- The shoulders on the edges of a runway and taxiway are paved but they are not capable of withstanding loads
- A paved blast pad about 45 m to 60 m in length is provided adjacent to the runway end to prevent erosion of the soil.
- The paved area of the blast pad is not designed to support the aircraft loads, but it may have the appearance of being so designed.
- The paint used is yellow.
- Runway shoulders are marked with diagonal stripes each having a width of 90 cm.
- The taxiway and holding apron shoulders are marked with stripes at right angles to the direction of travel of aircraft.
- The blast pad is marked with V shaped or chevron pattern marks.

Landing Direction Indicator

- To indicate the landing direction, an arrow or a tee is placed at the centre of a segmented circle. It indicates to the pilot the direction of the active runway of the airport.
- It is painted by orange or white color for being spotted with during day time and is lighted during night time.
- It is fixed at a distinct place.

Wind Direction Indicator

- The direction from which the wind blows is indicated at the airport by a wind cone.
- It is placed with in a segmented circle together with landing direction indicator.
- Wind cone length should not be less than 3.6m and its diameter should not be less than 90 cm.

Airport Lighting System:- Night Landing Aids

- Airport Beacon or Rotating Beacon
- Boundary Lighting
- Approaching Lighting
- Threshold Lighting
- Runway Lighting
- Taxiway Lighting
- Apron & Hanger Lighting

- Illuminated Wind Direction Indicator
- Illuminated Landing Direction Indicator

Approach Lighting System:-

- While approaching the runway for landing, the approach lights are the only elements of guidance to pilot.
- The lighting within the approach zone therefore must be such that the pilot is able to perceive the lights and has sufficient time to react and manoeuvre the aircraft to bring it to the correct alignment at a safe distance away and at adequate height above the runway level.

Runway Lighting System:-

- After crossing the threshold, the pilot completes a touchdown and then rolls the aircraft on the runway.
- The runway lighting is to plan that it imparts to the pilot the required guidance on alignment, lateral displacement, roll and height and distance, so that he is able to correctly judge his position in the space.

Air Traffic Control:-

- The need of air traffic control:
- To safeguard life & property.
- To expedite the traffic movements.
- No congestion & no delay.

Air Traffic Control grouped as below:

- Airport Traffic Control: To guide aircraft while take or landing. Movement on taxiway & apron.
- Airway Traffic Control: Movement of aircraft in the air.
- Airway Communication: Conveying of airway & weather information to the pilot during the flight.
- Nor-airway Traffic Control: Personal flying is done by a large number of people. In such cases, the movement of aircraft, not flying along the airway, must be regulated to prevent interference to the main air traffic.

Air Traffic Control Network:-

The network for controlling the air traffic can be divided into three parts as below:

Control within Terminal Area:

- Done form the airport control tower which is located in the terminal area.
- The control tower is nerve centre of an airport.
- Controller directs the movement of aircraft on the ground and in the air within the airport zone.
- Information like airport condition, airway traffic, visibility, speed & direction of ground winds, barometric pressure & other relevant information are provided to pilot for safe operation.

Control over Airways:

- The control is provided by a number of Air Route Traffic Control Centers (ARTC)
- In India, ARTC are provided at Bombay, Madras, Calcutta, Nagpur, Ahmadabad, Delhi & Jodhpur. Each centre controls a certain geographic area & thus cover the entire area of country.
- ARTC is mainly concerned with flights under Instrumental Flight Rules (IFR) conditions & not under Visual Flight Rules (VFR)

Airways Communication:

- This is usually done through flight service stations.
- These stations are located at the airports and also along the airways.
- To communicate air traffic control messages between the ARTC & enroute aircraft.
- To give certain information to the pilot, before and during the flights, regarding the weather change navigational aids, airports that are out of use & the procedure at a particular airports etc.

Air Traffic Control Aids:-

- During VFL weather conditions, flight is usually conducted by visual recognition of the objects on the ground.
- IFL are used when visibility is inadequate during night time or due to cloudy or foggy weather.

Air Traffic Control Aids are of two types:

Enroute Aids or Airway Aids & Landing Aids.

Enroute Aids or Airway Aid:

- Airway Beacon
- Low/Medium Frequency Ratio Range
- Very High Frequency Omni-Directional Range (VOR)

- Air ground Communication
- Tactical Air Navigation (TACAN)
- Marker Beacon
- Direction Finder
- Air Route Surveillance (ARSR)

Landing Aids:

- Instrumental Landing System (ILS)
- Precision Approach Radar (PAR) or Ground Approach Control (GAC)
- Airport Surveillance Radar (ASR)
- Airport Surface Detection Equipment (ASDE)
- Approach Lights

Vehicular Parking Area:

- The circulation of traffic and location of parking lots should be such that access to the terminal building is simple and convenient.
- Circulation of vehicular traffic within the terminal area is also carefully planned.
- Separate parking area is to be provided for the staff personnel.

The Aircraft Parking Configuration:-

- Size of loading area required for each type of aircraft. This area is also known as gate position.
- The aircrafts are parked causing the least interference due to heat, fumes and blast during maneuvering into and out of the gate position.

1) Nose in and Angle nose in
2) Nose out and Angle nose out
3) Parallel system

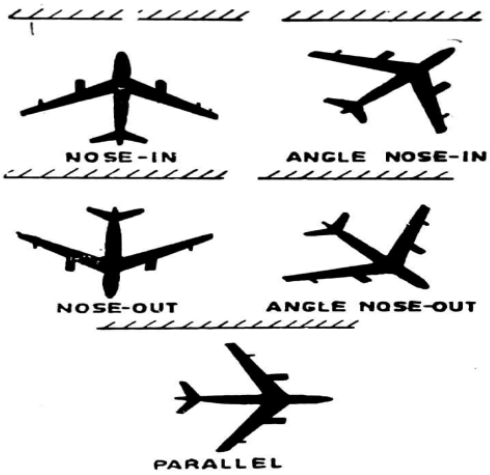

Fig. 26 Parking system

Aircraft Parking System:

Aircraft can be grouped adjacent to terminal building in various ways.

- Frontal System
- Open Apron system
- Finger System
- Satellite System

Frontal System:

- It is very simple and economical system. But its use is limited only to small airports requiring few gate positions.
- The aircrafts are parked along the face of the terminal building.
- It usually has an apron providing close-in parking for three to six commercial passenger aircraft.

Open Apron System:-

- In this system the aircrafts are parked in rows.
- If the number of aircrafts is too large, passengers may have to walk long distances.
- They are thus exposing to weather, noise and hot blast of the jet aircrafts, to protect the passengers from such nuisance, some sort of closed vehicle conveyance for the passengers may be essential.

Finger System:-

- Processing of passengers and their baggage is mainly done within the terminal building.
- But the facilities for the passengers, for entering and leaving the aircraft, often require extension of the terminal building. Such extension is known as Pier Finger.

Module IV

Harbour Engineering:

A harbour can be defined as a sheltered area of the sea in which vessels could be launched, built or taken for repair; or could seek refuge in time of storm; or provide for loading and unloading of cargo and passengers.

Harbours are broadly classified as:

- Natural harbours
- Semi-natural harbours
- Artificial harbours

Natural harbours:

- Natural formations affording safe discharge facilities for ships on sea coasts, in the form of creeks and basins, are called natural harbours.
- With the rapid development of navies engaged either in commerce or war, improved accommodation and facilities for repairs, storage of cargo and connected amenities had to be provided in natural harbours.
- The size and draft of present day vessels have necessitated the works improvement for natural harbours.
- The factors such as local geographical features, growth of population, development of the area, etc. have made the natural harbours big and attractive. Bombay and Kandla are, examples of natural harbours

Semi-natural harbours:

- This type of harbour is protected on sides by headlands protection and it requires man-made protection only at the entrance.
- Vishakhapatnam is a semi-natural harbour.

Artificial harbours:

- Where such natural facilities are not available, countries having a seaboard had to create or construct such shelters making use of engineering skill and methods, and such harbours are called artificial or man-made harbours.
- Madras is an artificial harbour.
- Thus, a naval vessel could obtain shelter during bad weather within a tract or area of water close to the shore, providing a good hold for anchoring, protected by natural or artificial harbour walls against the fury of storms.

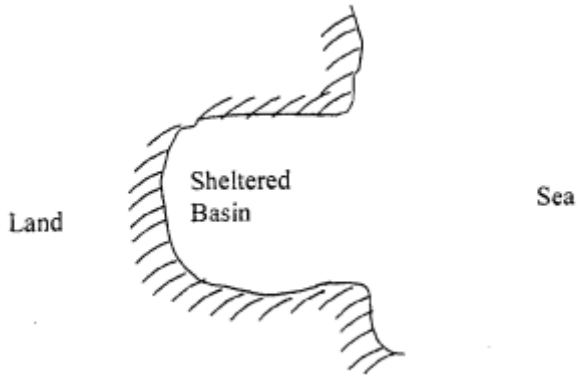

Fig. 27 Natural harbour

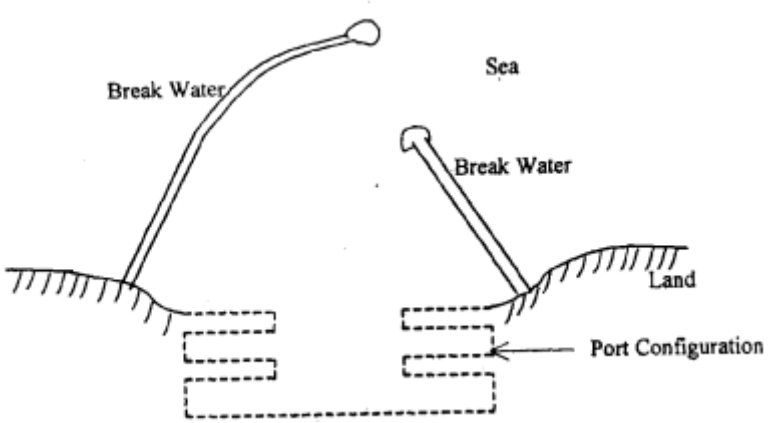

Fig. 28 Artificial harbor

Site selection:

The guiding factors which play a great role in choice of site for a harbour are as follows

- Availability of cheap land and construction materials
- Transport and communication facilities
- Natural protection from winds and waves
- Industrial development of the locality
- Sea-bed subsoil and foundation conditions
- Traffic potentiality of harbour
- Availability of electrical energy and fresh water Favorable marine conditions
- Defence and strategic aspects

Shape of the harbour:

The following principles should be kept in mind:

- In order to protect the harbour from the sea waves, one of the pier heads should project a little beyond the other.
- Inside the pier heads, the width should widen very rapidly.

- The general shape of the harbours should be obtained by a series of straight lengths and no re-entrant angle should be allowed.

Harbour Layout:

A harbour has the following constituent parts:

- An entrance channel, 100-300 m wide
- A turning basin, dia 400-600 m
- A breakwater, which protects the harbour from waves
- Docks, where ships berth
- Figure gives a typical layout of a harbour

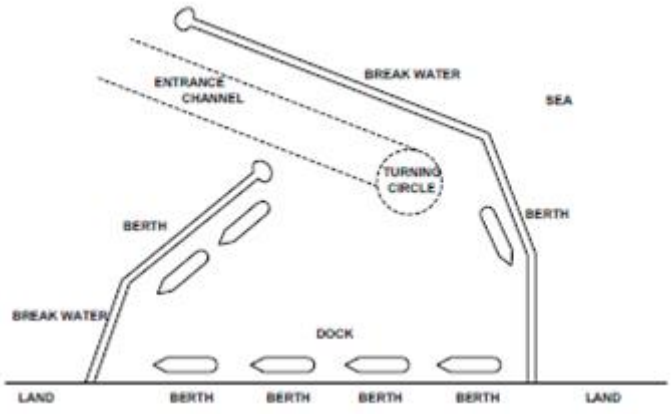

Fig. 29 Layout of Harbour

Docks

Docks arc enclosed areas for berthing ships, to keep them afloat at a uniform level, to facilitate loading and unloading cargo. Wet Docks are enclosed and are shut off by entrances or locks to maintain a fairly uniform level of water, and basins are partially enclosed areas of water, which are approached by open entrances and are subject to fluctuations of levels, due to tidal variations.

Classifications of docks

Docks can be classified into following two categories.

1. Wet docks

2. Dry docks

Wet docks

Docks required for berthing of ships or vessels to facilitate the loading and unloading of passengers and cargo are called wet docks. These are also known as harbor docks.

Dry docks

Dry docks, also known as Graving docks, are meant for repair of ships. They are basins made by excavations in the foreshore of the harbour, having entrances closed with gates and of such dimensions as to be capable of receiving, with adequate clearance, the maximum sized ship to be docked therein. The dry dock gate is first opened after the water level in the dry dock is equal to that of the water in the wet dock. The ship is floated into the dry dock, the gate is closed and the water in the interior is pumped out. The ship is made to settle on the keel blocks provided at the floor of the dry dock, and stays are provided to keep it in position. On completion of the repairs, the dock is flooded, the gate opened and the ship is allowed to move out. The dimensions of the dry dock are selected to suit the maximum dimensions of ships expected to use the dock. Width can be in the range of 20 to 30 m, length can be in range of 200 to 300 m and the depth can be in the range of 8 to 15 m. The walls and the floor must be watertight. They can be constructed in masonry or mass concrete.

Figure 20.15 Cross section of Dry Dock

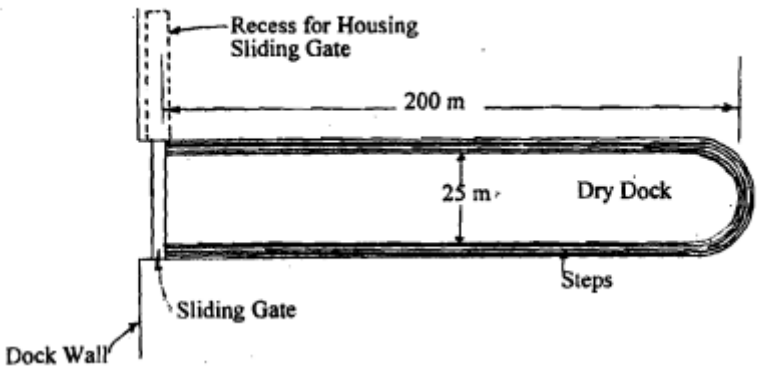

Fig. 30 Plan of dry dock

Advantages of wet docks:

- Uniform level of water is maintained which is very convenient for handling cargo.
- Prevents the rubbing of the ships sides against the quay walls.
- Effect of storms in the outer sea and harbour do not obstruct the dock enclosure.

Repair docks are necessary for the execution of repairs, cleaning and painting of ships bottom. Hence these docks and docking arrangements should be such as to expose, the ship's exterior fully and keep it out of water during the progress of repairs or renovation.

There are generally four classes of such docks viz:

1. ***Graving or dry dock. 2. Floating dock. 3. Marine railway. 4. Lift docks.***

Graving or Dry Dock:

The graving dock, also known as a dry dock is a long, excavated chamber, having side walls, a semicircular end wall and a floor. The open end of the chamber is provided with a gate and acts as the entrance to the dock. The below figure show the plan and an enlarged cross-section of a typical graving dock. The side walls are formed with a series of steps known as altar courses to receive the ends of the shores which support the vessel in a vertical position while being docked. The dock is constructed of concrete or masonry and the altar courses and steps.

Advantages of Graving Dry Dock:

- It can accommodate bigger size vessels when compared to other dry docking systems
- It is cheaper for dry-docking a similar-sized vessel as compared to other types
- The graving dry dock can be used to perform retrofitting, modification etc. which is difficult to achieve in other types
- The supply of spares, machinery, services to the graving dock is very much accessible due to its location-based near the land
- New advanced graving docks have welding, hot-work and other workshops located inside the dock on an elevated surface, (above the water surface when the dock is filled) giving quick access and workflow in the dock
- Retractable ramps in new types of graving docks make it easy to supply spare, machinery and saves a lot of time and manpower to transfer them inside the dock
- A bigger graving dock can be used to repair more than two ships at a time and some modern graving docks have two gates at both ends, making it easier to repair and re-float the ships independently

Disadvantages of Graving Dry Dock:

- When re-flooding the dry dock, all the machinery and equipment needs to be taken out from the dock, which takes time

- The maintenance cost of the graving dock increases as per the age of the dock and becomes very high
- Any problem with the dock gate will make the whole dock non-operational

Floating dry dock;

A floating dock is in the form of a "U" structure which is mainly used in salvage, to carry ships that have met with an accident and are damaged to an extent that has made them unable to sail further to a coastal dock.

However, now many regular sea-going, small and mid-size vessels are also dry docking in a floating dock. Several "U" type floating docks can be joined to carry a large vessel.

The ship is brought near the channel where the floating dry dock will partly submerge itself and the ship slides inside the dock. Once the ship is in the position, the floating dock is then de-ballasted to drain the water from its hollow floors and walls to support the vessel on the blocks arranged on the floor of the floating dock.

Advantages of a Floating Dry Dock:

- They can be propelled to the location of a salvage vessel near the harbour
- They are cheaper to maintain as compared to graving docks and can get a higher resalable return
- They can be installed near or away from the shore inside the harbour, making them a portable and space-saving structure without taking space of the shore facility
- The complete floating dry dock can be aft or forward trim by ballasting the dock, which further assists the ship or the damaged vessel which cannot be given a trim
- Additional mooring equipment is needed for the floating dry dock to make it stable
- The floating dry dock can be altered and increases in size in all dimensions by extensive retrofitting/ rebuilding
- They can also be split into two different floating docks independent of each other

Disadvantages of floating dry Dock:

- The supply of store, equipment, and manpower is usually done from one access point gangway which makes the operation slow

- The maintenance cost of the floating dry dock is similar to that of a ship as the hull of the floating dock is submerged in the saltwater
- The floating dry dock operation will effect if there are tides or during windy weather
- When re-flooding the dock, all the machinery and equipment needs are to be taken out from the dock which takes time

Choosing a type of Dry Dock

The criteria to select a type of dry dock for a ship depends on the following factors:

- **The size of the vessel:** The graving dock is used to accommodate larger sizes as compared to any other type. If the ship owner/ manager has to dry dock a large oil tanker, they will go for graving dock. If the vessel is about 10000 tones, the Marine railway type can be used. If a boat or small yacht of up to 250 tones needs a repair in the dock, a mobile marine lift can be used
- **The condition of the vessel:** If the vessel propulsion plant is not working or there are damages that can make a vessel immobilized, floating docks are commonly used in such a condition
- **Types of repair:** The choice of the type of dry dock also depend on the types of repair the ship wants to undergo. For the normal scheduled dry dock, a floating dock can be selected, however, if there are major retrofitting or massive parts/ machine fitting is required, the graving dock is selected as they are usually located near to the shipyard and it is easy to move the material from land to dock as compare to the floating dock
- **Schedule of the Vessel:** The location and the type of the dry dock will be decided as per the current schedule of the vessel and how easy it is for the ship to reach the dock after unloading all the cargo to the last port of call
- **Budget:** The most important factor to select the type of dry dock is the budget allotted to the ship

Marine railway docks

Marine railways are more susceptible to climate and water changes than graving docks and dry docks. Working conditions for vessel overhaul are favorable when using a marine railway, as the railway will lift vessels above the water level and allow workers to work in and around the ship.

Selecting a Marine Railway Site

There are five specific requirements that must be met for any marine railway site:

- Sheltered harbor
- Channel of adequate depth and width
- Suitable soil or rock foundation
- Satisfactory tidal, current, silting and climatic conditions
- Sufficient area and suitable sites for all proposed related facilities

Design Criteria for End haul Marine Railways

There are three basic components to a marine railway system: a cradle, track and machinery/hoist house.

- While the specific design criteria for each component will depend on the particular project, there are some general considerations that should be taken into account for all marine railway construction.
- Marine railways are designed for docking vessels at mean high water when the deck of the cradle is entirely dry.
- As a result, the vertical cradle rise which must be provided for in-the-track design is the sum of its vertical dimensions.
- Large marine railways are typically built with track slopes of either 3/4 or 7/8 per foot.
- The height of the blocks at the inshore end of the cradle should be as low as possible to avoid the necessity of high blocks at the offshore end of the cradle.
- The length of the track will vary based on whether it is a roller system or wheel system.
- For cradles with wheels, the minimum required length is the sum of the distance the cradle must travel to rise the determined vertical height and the length of blocks on cradle.
- For roller trains, the length is determined by determining the minimum length of tracks for wheels and adding the length of two roller sections.
- The minimum total track length is the minimum track length plus the distance required for necessary clearances and the hoist house. The ideal total track length would add an additional 100 feet inshore to permit hauling the cradle out of the water for inspection and repair.
- The machinery or hoist house must contain the hauling machinery. This will include an electric motor, a train of reduction gears, and the wildcat or wire rope drum.

- In addition, a clear, paved space should be permitted at the rear of the hoist house to allow for wheeled traffic.

Waterways

Water transportation: The water transportation can further be subdivided into two categories:

- Inland transportation and
- Ocean transportation.

Inland water transport

The waterways can be:

- Canals
- Rivers
- Lakes
- Backwater of seas
- Bays

Advantages

The advantages of IWT operations are:

- They are very economical to operate
- They involve minimum of investment on channels and vessels
- They are highly labour intensive and generate considerable employment
- They are pollution free
- They make little demands on land

Shortcomings

- Slow speed
- Seasonable limitations
- Low accessibility
- Involve transshipment and multi-model movement

Ocean Transport

Coastal Shipping:

It is one of the most important means of transport for carrying goods from one part to another in a country. It is a cheaper and quicker mode of transport and is most suitable for carrying heavy, bulky and cheap traffic like coal, iron ore, etc. to distant places. But it can serve only limited areas. Earlier, coastal shipping in India was mainly in the hands of foreign shipping companies. But now from 1951 onwards, it is exclusively reserved for Indian ships.

Overseas Shipping:

Ocean transport is indispensable for foreign trade. It has brought the different parts of the world closer and has knitted together all the nations of the world into one big world market. It operates on a natural track, i.e., the sea does not require any investment in the construction and maintenance of its track. Below are three types of vessels employed in the overseas shipping:

(i) Liners:

Liners are the ships which have regular fixed routes, time and charges. They are, usually, a collection of vessels under one ownership, i.e., a fleet. They provide a uniform and regular service. Liners sail on scheduled dates and time, whether full of cargo or not.

(ii) Tramps:

Tramps are ships which have no fixed routes. They have no set rules or rate schedule. Usually, they do not sail till they have full cargo. They can be chartered by exporters and are ready to sail anywhere and at any time. They are not as fast in speed as liners. Tramps are more suitable to carry seasonal and bulky goods.

(iii) Tankers:

Tankers are the vessels which are specially designed to carry oil, petrol and such other liquids. They have a large capacity, 2 to 3 lakh tons of oil, and very shortly, super tankers with a capacity of about 10 lakh tons of oil will be available.

Economics of inland waterways transportation

Water transport plays important role in foreign trade. India's foreign trade is mainly dependent on water transport. Maritime logistics has been an important component of the Indian economy, accounting for 90 per cent of EXIM trade by volume and 77 per cent by value.

- Development of shipping is essential for the defense of the country also. It is also called second line of defense.
- Water transport channel is quite cheap as compared rail and road Transport. Oceans and rivers are the free gifts of nature. It operates on a natural track and hence does not require
- Huge capital investment in the construction and maintenance of its track except in case of canals.
- Maintenance cost in rail and road transport is quite high but maintenance cost of water transport is quite less.
- Heavy and bulky goods can be transported easily at little cost through water transport.
- During natural calamities like flood and rains, when rail and road transport is disrupted, only water transport can be operated.

- It is considered as the most useful method from the point of view of energy saving. One horse power can carry 4,000 kilogram load in water whereas, it can carry 150 kilogram and 500 kilogram load by road and rail respectively.
- There is lesser pollution in water transport.

National Waterways

National Waterways, also known as NWs, are like special roads, but instead of running on land, they sail on water! They are artificial or natural water channels that the government develops and maintains for transportation purposes. Just like roads, these waterways have specific numbers and names to make them easy to identify. The country is bestowed with a plethora of diverse topography which enables different kinds of transportation. India has about 14500 km of navigable waterways. This includes rivers, backwaters, canals, creeks, and so on.

- **National Waterways Act** came into effect in 2016. It proposed 106 additional National Waterways and merges 5 existing Acts which were declared the 5 National Waterways. As a result, 106 new waterways were identified by IWAI and intimated to MoS. In this regard, the National Waterways Act, 2016 was published in the Gazette of India, Extraordinary, Part II, Section I dated 26th March, 2016 as an Act No. 17 of 2016
- In 1986, the Government of India created the Inland Waterways Authority of India (IWAI) for regulation and development of Inland Waterways for navigation and shipping.
- Out of the 111, National Waterways declared under the National Waterways Act, 2016, 13 are operational for shipping and navigation and cargo/passenger vessels are moving on them.

Development of waterways in India

- The development of waterways in India refers to the improvement of water bodies for transportation and trade purposes. It involves making these water routes navigable and facilitating the movement of goods and people through them.
- Waterways have played a significant role in India's transportation system for centuries. The development of waterways aims to enhance connectivity, reduce transportation costs, and promote economic growth.
- To develop waterways in India, various measures are undertaken. These include dredging and deepening of rivers and canals to ensure sufficient depth for navigation. The construction of barrages, dams, and locks helps regulate water flow and maintain navigability. Building terminals, jetties, and ports along the waterways facilitate the

loading, unloading, and storage of cargo.

- The development of waterways in India is supported by the government through initiatives. This includes the National Waterway Act and the National Waterway Authority. Efforts are made to integrate waterways with other modes of transportation, such as road and rail.
- The development of waterways offers several advantages. It reduces congestion on roads and railways, saving time and costs. It provides an alternative mode of transportation, particularly for areas inaccessible by road or rail.