UNIT-1
RAILWAY PLANNING AND DESIGN

ROLE OF INDIAN RAILWAYS

- The area covered by the Indian railways is about 3 260 009 square kilometers spanning over 4000 km from Srinagar and further in the north of KanyaKumari in the south and over 2700 km from Bombay in the west to Gauhati and further in the east.
- The tot land with the railways is about 4.19 lakh hectares. There are four gauges in India
- There is no railway station where all four gauge meet.
- But three gauges meet at the following stations:.
  - Bangalore city — 1676 mm, 1000
  - New Jalpaiguri — 1676 mm, 1000
  - Ujjain— 1676 mm, 1000

The development of the Indian railways can be divided into five stages:

(1) The old guarantee system
(2) State construction and ownership
(3) The modified guarantee system
(4) Nationalism
(5) Integration and regrouping

The old guarantee system (1849-1869):

- During the initial stages, the old guaranteed system prevailed.
- There were eight railway companies covered up by the system and they entered into contracts with the East India Company for running the railways.
- The essence of the con
tracts was that the shareholders were relieved of all risk and they were given expectation to receive certain profit over and above the guaranteed interest.
- The ultimate right of purchase and full powers of supervision vested with the government.

State construct/on and ownership (1869-1882):

- It was felt that the administration of the railway companies was not upto the standard and hence from 1869,
- the next phase of State Construction and Ownership was accepted and it lasted upto 1882 during which the government purchased the existing railways and constructed new lines.

The modified guarantee system (1882-1924):

- From 1882-1924, the period of the modified guaranteed system came into force during which various small princely States of India, existing at that time, contributed to the extent of about 12 165 km to 41 279 km of railway lines owned by the government of India at that time.
- The first Indian State to own a railway line was Baroda in 1873 and followed by various other states Hyderabad, Morvi, Bhavnagar, etc.
- The last State to own a railway line was Bahawalpur in 1911.
- In a similar way, a large number of other lines, mostly narrow gauge branch and feeder lines, were built by companies under various contracts.

Nationalisation (1924-1944):

- The public opinion was consistently in favour of State management and ultimately the government appointed a committee in 1920 under the chairmanship Of Sir William M. Acworth,
- An international authority on railways.
- The committee consisted of 10 members out of which 3 were Indians.
- The committee gave detailed report on railway policy, finances and administration of railways.
- The recommendations of Acworth committee were mostly accepted by the government and the railways were nationalized from 1924 and the process of nationalization of Practically the entire railway system in India was completed by 1944.

Integration and regrouping (1944-1966):

- On the country's Independence, there were still as many as 42 railway units which were subsequently merged to form the Indian Government railways, the largest public sector undertaking of the country.
- With the integration of princely States after independence of the country, the stage was set up for the formation of different railways into a small number of zones.

- .Starting with the first zonal railway, the Southern Railway (SR.) on 14-4-1951, the ninth zonal railway, the South Central Railway (S.C.R.), was carved on 2-10-1966.
- The other zonal railways are Central Railway (C.R.), Western Railway (W.R.), Eastern Railway (ER.), Northern Railway (N.R.), South Easter Railway (S.E.R.), North East Frontier Railway (N,E.F.R.) and Ndrth Eastern Railway (N.E.R.)

Further the Indian railways have proved to be a model employer as the following facilities are provided for the welfare of staff:

Education:

- The railways run and maintain 684 colleges and schools; 7 intermediate colleges; 85 secondary schools; 29 middle schools and 562 primary schools to give facility for the education of children of their employees.
- The annual expenditure for this facility exceeds Rs. 10 crores.
- In addition, 14 subsidized hostels have been set up in major linguistic areas for employees who have to send their children far away from their headquarters for the purpose of education.

Medical treatment:

- The railways provide the medical service to all the employees without distinction either in extent or quality.
- The medical department of the Indian railways is a vast organization having as many as 119 hospitals with over 12 517 beds for in-patients and 670 health units.
- The strength of staff is about 2600 doctors, 4000 nurses and 53 000 para-medical staff.
- The Indian Railways also provide super-speciality units such as open heart surgery at Perambur, Madras;; orthopaedic unit at Howrah; plastic surgery unit at Bombay; and cancer institute at Varanasi.
- The annual expenditure for this facility exceeds Rs. 108 crores.
- As a matter of fact, efforts are made to introduce door-to-door medical services for the staff so that each and ever railwayman can take the benefit of these facilities.

Staff benefit fund:

- The railways maintain staff benefits fund and the activities such as scholarships for technical courses for childrens of employees, mobile libraries, handicraft centres for women members of employees, vocational training centres for employees, scouting, etc. are 1 from this fund.

Housing:

- The railways have put up nearly 545 000 quarters to accommodate bout 38 per cent of staff and these quarters to the extent of about 73 per cent are electrified. The staff has to pay nominal rent at highly subsidized rates.
- The railways have also encouraged the formation of co-operative housing societies by the raitwaymen
- The Indian Railway Welfare Organization (IRWO) has been set up in 1989 for Providing a house to every railwayman on no profit no loss basis in 70 prominent cities and towns of the country.

RAILWAY SURVEYS

Reasons for laying a new railway line:

A new railway line is required or is proposed for the following purposes

Strategic consideration:

- It becomes essential to join two points by a railway line for strategic purposes so that in case of emergency, the army can be transferred from one point to the other.

Linking of trade centres:

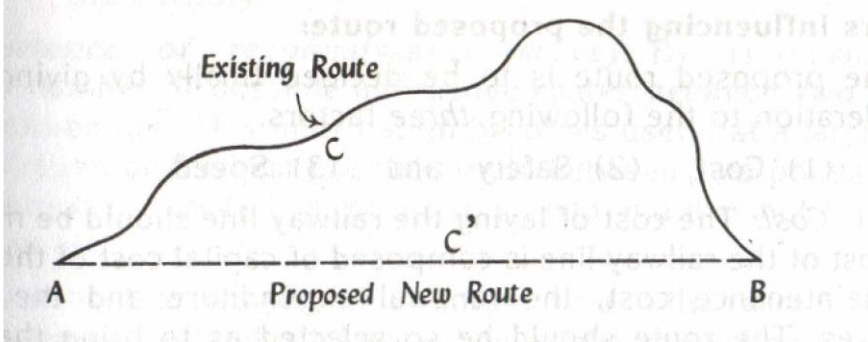
- The two trade centres may not be linked up by a railway line.
- In such cases, a new railway line are proposed between two such trade centres.

Connecting port with the interior of the country:

- A port is sometimes not connected with the interior of the country.
- In such cases, it becomes essential to have a new railway line joining the port and the trade centres of the interior of the country.

Shortening existing route:

- A route exists between two points.
- But if it is possible to shorten the existing route, a new railway line is to be laid.

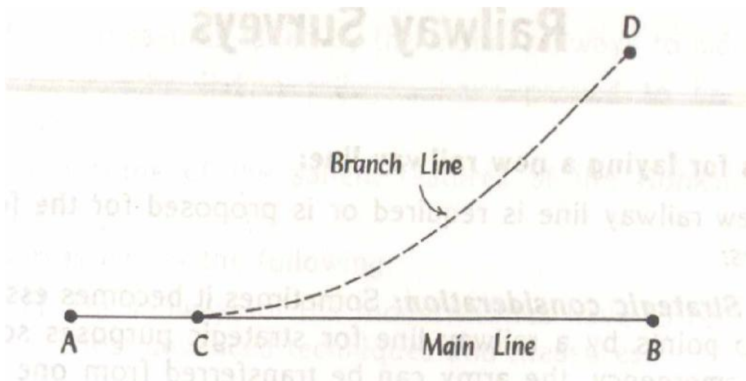


Existing route and proposed new route

- ACB is an existing route which can easily be replaced by a proposed AC'B route.
- Thus the length of the line will be shortened and in some cases, it results in opening up new traffic way by joining certain important cities on the proposed route.
- However it should always be remembered that no railway line should be made short at the expense of bad gradient or losing valuable way or affecting local traffic.

<u>Laying of a branch line</u>:

- It becomes necessary sometimes lay a branch line to an existing main line to develop certain other cities on the proposed branch line.
- The new branches line will serve as feeder line for the existing main railway line.



A branch line from a main line

- AB is the existing main line and C is the proposed branch line which will help in the development of city D.

<u>Undeveloped area</u>:

- The new railway line is laid to develop an area which may be rich in mineral resources or other natural wealth like timber resources.
- It may however be noted that apart from the purposes mentioned above, there are cases in which the railway lines are to be laid to promote economic development of the area, even though the proposals of laying such lines are not financially sound.

<u>Factors influencing the proposed route</u>:

The proposed route is to be decided finally by giving serious consideration to the following three factors:

(1) Cost, (2) Safety and (3) Speed.

Cost:

- The cost of laying the railway line should be minimum
- The cost of the railway line is composed of capital cost of the project, the maintenance cost, the renewal expenditure and the working expenses.
- the route should be so selected as to bring the sum of all these costs to a minimum,

Safety:

- The available passenger and goods traffic should be transported safely by the railways.
- This means that the new route should be so laid as to have minimum chances of train accidents.

Speed:

- The route should be so selected as to have reasonable speed of trains,

Railway surveys:

The various engineering surveys which are carried out for the Choice of a route of a new railway line can broadly be divided into the following three categories:

- Reconnaissance survey
- Preliminary survey
- Location survey.

Reconnaissance survey

Objects of reconnaissance survey:

- A reconnaissance survey is the first engineering survey that is carried out in territory which has not been previously surveyed for the purpose of laying a new railway line.

The main objects of reconnaissance survey are as follows:

(1) to obtain the general knowledge of the whole territory, and

(2) to obtain the information regarding the salient features of the territory.

Importance of reconnaissance survey**:**

- By reconnaissance serious survey, a number of possible alternative routes between two points can be worked out.
- This information becomes useful at a later stage in the selection of the best possible route between two points.
- Thus minimum reconnaissance survey is a means to an end and it is not a science project, but it is an art.
- The personal factors play an important role in the reconnaissance of survey.
- It should be conducted according to certain guiding principles rather than certain fixed rules.

- The successful conduct of the be reconnaissance survey entirely depends on-the personal qualities of the engineers such as his training and experience, his capacity of Observation and interpretation of the features of the territory, etc.

A reconnaissance survey can broadly be divided into two categories:

- Traffic reconnaissance survey
- Engineering reconnaissance survey.

Traffic reconnaissance survey:

This survey consists of collection of the information regarding the following:

- the general character of the country and the extent cultivation;
- the information regarding the local industries and religious festivals;
- the general condition as regards prosperity of people in the locality and density of population and it distribution;
- the probable amount of traffic to be served by new railway line;
- the probable new traffic lines to be opened up to join. large centres of trade;
- the nature and volume of exports and their destination;
- the amount of imports and centres of their distribution;
- the possibilities of development of industries as a result of the new railway line and any other public works such as irrigation scheme to cover the area;
- visiting all trade centres and consultation with prominent citizens and local authorities regarding the most suitable route for the railway
- the standard of construction required for carrying the probable traffic;
- the study of the existing means of transport;
- the estimation of passenger and goods earnings
- separately and comparing with actual figures of other similar existing lines

Engineering reconnaissance survey:

This survey consists of collection of information regarding the following:

- the physical features of the country;
- the surface formation of the ground;
- the nature of soil and its classification;
- the streams and rivers of the immediate vicinity especially those which are likely to cross the proposed railway line
- the positions of hills and lakes;
- the samples of water from wells, rivers, etc. so as to ascertain weather the water is suitable for use locomotive or not;

- the availability of materials and labour for use during construction.

Factors should be kept in view in reconnaissance survey:

Area

- A reconnaissance survey should be carried out for the whole area of country.
- It should never be carried out for a line only.

Existing roads

- A reconnaissance survey should not be guided by the existing roads because the ground which is favourable for construction of roads may not be useful for the construction of a railway line.

Starting of route

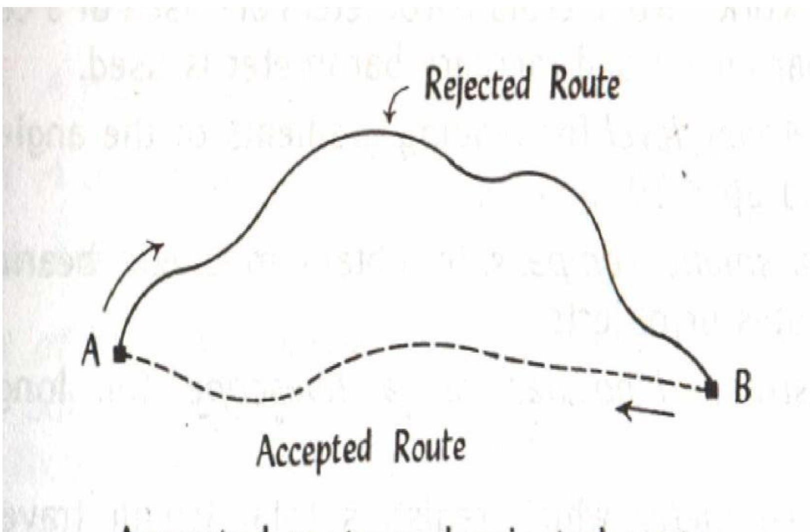
- The engineer should not reject a particular route simply because it starts badly i.e. with Curvature or with sudden rise or fail, etc.
- He must ascertain that the route continues badly for a long distance.

Assumptions

- The assumptions should be made very carefully as sometimes they are likely to be proved wrong, when tested by actual observations.

Survey route:

- A and B are two control points as shown in fig. and the reconnaissance survey should be carried out from A to B and from B to A for independent studies.



Accepted route and rejected route

- It is most likely that route from A to B while starting point A may lead into difficult construction and therefore may to be rejected.
- But the same route while starting from B to A be found practicable and acceptable.

Ocular illusions

The ocular illusions should be prevented. The most common illusions are as follows:

- estimating wrong length of line or offset;
- estimating wrong curvature;
- overlaps of hills which may appear as a continuous ridge from a distance. But actually, It may have an open valley at the overlap;
- in flat countries, the observer finds a lake or a flowing river at a distance but in fact, no such thing exists.

Revenue

The probable revenue from the proposed railway line may be worked out by keeping in view the following facts:

- In the first stage, the contribution of traffic comes from area of about 15 km wide strip on either side of the railway line. This width extends as railway line grows in age.
- The estimation of expansion of traffic should be made: for a maximum period of about five years or so.
- By studying the statistics of development of a similar existing track, the amount of revenue per head of the• population may be decided.
- Multiplying this figurer by the probable population to be served, the remunerativeness of a proposed new railway line may be worked out.

Instruments for reconnaissance survey:

Following instruments are required while conducting a reconnaissance survey:

- An aneroid barometer which is an instrument used for determining the relative heights of various points. It should be remembered that ordinary aneroid barometer does not record minor difference in elevation, say upto about 6 to 8 metres. Hence sometimes for accurate work, two aneroid barometers are used or a combination of aneroid barometer and mercury barometer is used.
- An Abney level for reading gradients or the angles of slope of the ground upto 10 minutes.
- A prismatic compass to obtain magnetic bearings of the proposed routes or objects.
- A strong binocular or a telescope for long distance observation

- A pedometer which registers total length traversed by a person. It should be adjusted for the average width of step of the engineer and should be kept in vertical position during its use.

Preliminary survey:

Object of preliminary survey:

- The object of preliminary survey is to conduct the survey work along the alternative routes found, out by reconnaissance survey and to determine with greater accuracy
- the cost of the railway line along these alternative routes and to decide which route will be the most economical.
- Thus, in prelirninary survey, all the possible routes of railway line are critically studied examined and analysed.

Importance of preliminary survey:

- The preliminary survey decides the final route and recommends only one particular route in preference to other alternative routes.
- thus the preliminary should be carried out with great precision as on it depends the alignment of the final route.

Work Of Preliminary Survey:

- The cross-sections are taken at all representative points along the route and the features of the country are marked
- The cross-sections are taken for a distance of about 150 metres on either side of the railway route.
- The contour plan are then prepared.

Instruments for preliminary survey:

- The instruments to be used in the preliminary survey will depend upon the character of country. The most common instruments to be used for this purpose are as follows:
    - A dumpy level
    - A tacheometer
    - A plane table
    - A prismatic compass.

Location survey:

Object of location survey

- The main object of location survey is to carry out the detailed survey along the route which has been found and fixed as the most economical route from the data of the preliminary survey.

Importance of location survey

- The location survey establishes the centre of the actual track to be laid and hence, as soon as the location survey is completed, the construction work is started.

- Thus the end of location survey is the beginning of the actual laying of new railway line.

Work of location survey: The location survey is carried out in the following two stages:

(1) Paper location

(2) Field location

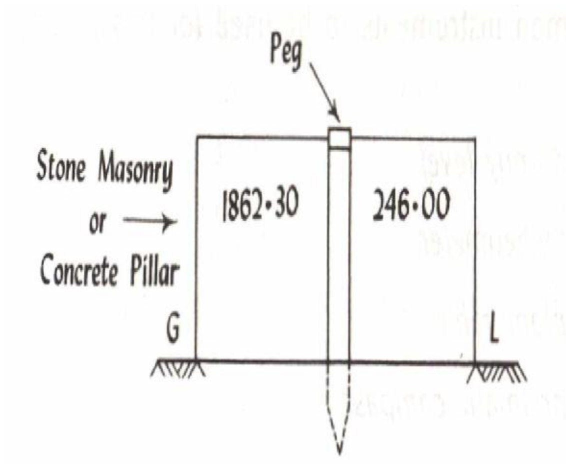
Paper Location

- The final route selected is put up on paper and details such as gradient, curves, contours etc., are worked out.
- All the working drawings are prepared, even of minor structures such as signal cabins.

Thus, after the paper location is over, the field work is started and the centre-line of the track is fixed.

Field location

- The field location transfers paper location on the ground so that it might have as good a profile as it has on paper location.
- Moreover it gives all the requirements of the construction engineer such as bench-marks, levels, measurements, etc
- The centre-line pegs are driven at every 300 metres along the centre-line of the track.
- Every change of direction, the beginning and end of the curve and also the intersecting points are clearly marked.
- Sufficient bench-marks are established at distances of not rnore than 800 metres to which the levels can be referred and the gradients can be transferred.
- These centre-line and other pegs are surrounded by stone masonry or concrete pillars on which the chainage and levels are marked.



- In addition to the fixing up of the centre-line of the track, the centre-lines of bridges culverts tunnels station buildings, yards, signal cabins, etc. should also be fixed.
- In case of bridge and tunnels, sufficient data should be available from field location for setting out the centre-line, both as regards direction and level.

Instruments For Location Survey

The instruments to be used are as follows:

(1) A theodolite

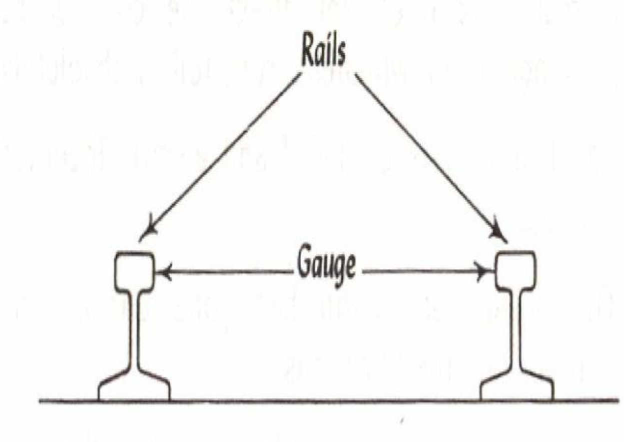
(2) A precise level

(3) A steel tape.

Rail Gauges

DEFINITION

The gauge of a railway track is defined as the minimum perpendicular distance between the inner faces of the two rails as shown in fig.



Gauge

The factors affecting the choice of a gauge:

Traffic condition: If the intensity of traffic on the track is likely to be more, a gauge wider than the standard gauge is suitable

Development of poor areas: The narrow gauges are in certain parts of the world to develop a poor area and thus the poor area with the outside developed world.

Cost of track: The cost of railway track is directly proportional to the width of its gauge. Hence, if the fund available is not sufficient to construct a standard gauge, a metre gauge or a narrow gauge is preferred rather than to have no railways at all.

Speed of movement:

The speed of a train is a function of the diameter of wheel which in turn is limited by the gauge. The wheel diameter is usually about 0.75 times the gauge width and thus the speed of a train is almost proportional to the gauge. If higher speeds are to be attained, the B.C. track is preferred to the MG. or N.G. track

Nature of country In mountainous country, it is advisable to have a narrow gauge of the track since it is more flexible and can be laid to a smaller radius on the curves. This is the main reason in which some important railways covering thousands of kilometres, are laid with a gauge as narrow as 610 mm.

The different gauges can broadly be divided into the following four categories.

Broad gauge:

Width 1676 mm to 1524 mm or 5'-6 to 5'-O'

Standard gauge:

Width 1435 mm and 1451 mm or 4'-8 and 4'-9

Metre gauge:

Width 1067 mm, 1000 mm and 915 mm or 3'-6',
3'-3 and 3'-0
8

Narrow gauge:

Width 762 mm and 610mm or 2'-6' and 2'-O".

Uniformity In Gauges:

Difficulties to passengers:

- At the point where there is a change of gauge, the passengers are required to move from one train to the other.
- This transfer involves difficulties such as getting accommodation in the new train, transferring luggage from one train to other, climbing staircases of over bridges, etc.
- Moreover the timings of the two trains are to be correspondingly adjusted.
- Sometimes this may result in missing the train and then passengers have to pass the time on the platforms.
- Moreover the insanitary conditions will be developed on the platforms due to their constant use.

Difficulties for sending goods:

- The above cause is not so serious as trans-shipping i.e. loading and unloading of goods at the junction of two gauges.
- The passengers can make their own habits and pull on with the change of gauge.

But many difficulties are Involved in trans-shipping such as:

- The labour required for loading and unloading the goods may go on strike and thus completely dislocate the movement of essential goods required for various trades.
- The problem gets further Complicated for goods sent loose or in bulk such as coal, lime, limestone, stone chips, etc. because it is observed that at every trans.-shipment point, there are certain groups of laborers which are specialised in the handling of such materials.
- Hence it becomes difficult to employ other labourers in an emergency, even though there may be considerable unemployment in the area.
- It is most likely that delicate goods may be damaged during e process of loading and unloading.
- The thefts or misplacement of goods may occur during the trans-shipping which may lead to inconvenience to the persons concerned and long unnecessary correspondence are thus unduly created
- The large costly yards are to be provided at the junction of the two gauges to store the goods.
- One or more extra charges will have to be paid by the owner of the goods which will result in the increase in cost of the product.

Inefficient use of rolling stock:

- It is quite clear that wagon of metre gauge cannot be used on a broad gauge.
- Thus, sometimes this results in artificial shortage of wagons. Many wagons may be lying idle on the broad gauge line while there may be a acute shortage of wagons on the metre gauge line.
- Had there beer a uniform gauge, such difficulty would never have arisen.

Difficulty in war:

- If the gauge is not uniform throughout the Country, it becomes difficult to transfer the army by rail from one corner of the country to the other corner of the country in a very limited amount of time.

Equipment at station:

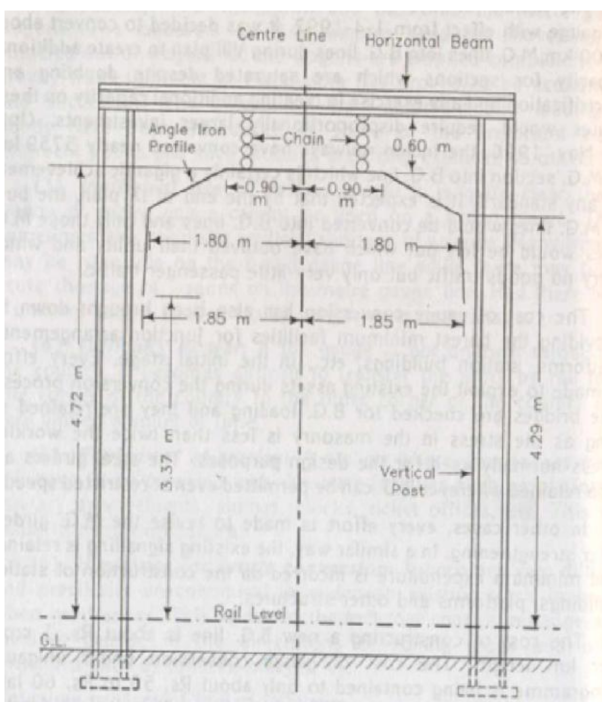
- A station where two gauges meet will have to be provided with duplicate facilities such as platforms, sanitary arrangements, sidings, clocks, ticket offices, etc. This will result in extra expenditure.

Hindrance for future con version

- It becomes very difficult and practically uneconomical to widen an existing track in future when need arises.
- This is due to the fact that change in gauge also involves change in the dimensions of rolling stock and other structures such as tunnels, bridges, etc.

Loading gauge and construction gauge:

- The loading gauge consists of a vertical post with an arm.
- A steel arc is suspended from the top. It is generally situated at the exit of goods yard and its main function is to show or to confirm whether the tops of the Loads would clear up all the structures such as bridges, tunnels, etc. along the route.
- Thus the loading gauge represents the maximum width and height upto which the wagons can be loaded. Fig. shows a dimensioned sketch of a typical loading gauge on a broad gauge track.



Loading gauge

- The loading gauge is derived from another gauge, known as the construction gauge.
- By adding suitable clearances at the top and sides of the loading gauge, the dimensions of construction gauge are obtained and it thus decides the width and height of various constructions such as bridges, tunnels, etc. along the route.
- It also decides the maximum dimensions of the rolling stock.

Permanent way and its components

Definition

The finished or completed track of a railway line is comrnonly known as the Permanent Way.

It essentially consists of the following the parts:

- Rails
- sleepers
- Ballast.

The rails are fixed with each other by means of various rail fastenings and they rest on sleepers which are laid at right angles to them.

The main requirements of an ideal permanent way:

- The gauge of track should be uniform and there should not be varying gauges.
- There should be minimum friction between the wheels of rolling stock and the rails.
- The facilities should be provided at various 0 along the permanent way to repair, replace or renew the damaged portion of the track.
- The design of the permanent way should be such that the load of the train is uniformly distributed over it
- The components of the permanent way should be so selected as to produce a permanent way with a certain degree of elasticity to prevent the shocks due to impact.
- The gradient provided on the permanent way should be even and uniform.
- The special attention should be given on the design of permanent way on curves.
- It should possess sufficient lateral rigidity and vertical stiffness.
- The overall construction of the permanent way should be such that it requires minimum of maintenance.
- The permanent way should possess high resistance to damage at the time of derailment.
- The various components of the permanent way should possess anti-sabotage and anti-theft qualities.

- The drainage facility should be perfect.
- The precautions should be taken to avoid the occurrence of creep
- The rail joints should be properly designed and maintained.
- The alignment of track should be free from kinks or irregularities.

Functions of rails

Following are the three functions or purposes of rails in a railway track:

(1) to bear the stresses developed due to heavy vertical loads

(2) to provide a hard and smooth surface for the passage of heavy moving loads with a minimum friction between lateral and braking forces, and thermal stresses; the steel rails and steel wheels; and

(3) to transmit load to the sleepers and consequently to reduce pressure on ballast and formation.

Requirements of an ideal rail:

Following are the requirements of an ideal rail for the railway track:

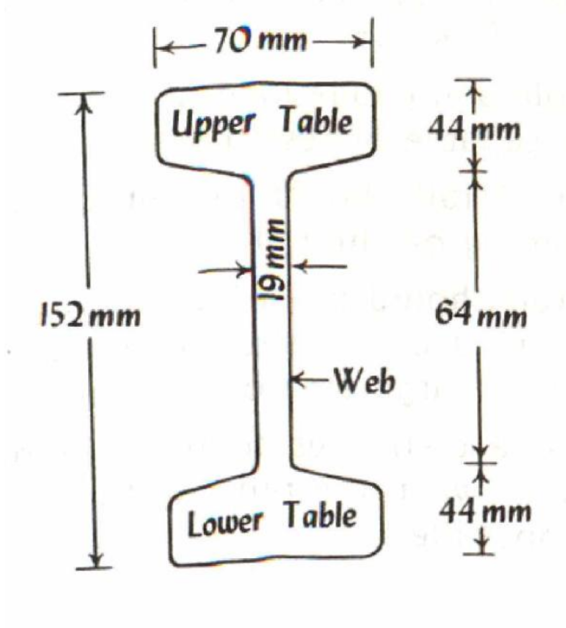
- The rail section consists of three components: head, web and foot. It should be designed for optimum nominal weight to provide for the most efficient distribution of metal in its various components.
- The bottom of head and top of the foot should be give such shapes that the fish-plates can easily be fitted.
- The centre of gravity of rail section should be located very near to the centre of height of rail so that maximum tensile and compressive stresses are more or less the same.
- The depth of head of rail should be sufficient to allow for adequate margin of vertical wear:
- The rail should possess adequate lateral stiffness and vertical stiffness.
- The rail table should be suitably shaped. It is generally a shape of a compound curve consisting of 3 curves with radii of about 80mm, 300mm and 80 mm.
- There should be a balanced distribution of metal in head, web and foot of rail so that each of them is able to fulfil its assigned function.
- The surfaces of rail table and gauge face of rail should be hard and should be capable of resisting wear.
- The thickness of web of rail should be sufficient to take safely the load coming on the rail
- The width of foot of rail should be sufficient to grant stability against overturning and it should be capable of spreading the load on a large area of the sleeper.
- To bring down the contact stresses to the minimum level, the contact area between the rail and the wheel should be as large as possible

The steel rails can be broadly divided into three categories as follows:

- Double headed rails
- Bull headed rails
- Flat footed rails.

Double headed rails :

- This type of rail consists of three parts
    - upper table,
    - web and
    - lower table.
- Both the upper and lower tables were identical and they were introduced with the hope of doubling the life of rails.
- When the upper table was worn out, the rails can be reversed in the chair and thus the lower table can be brought into use.



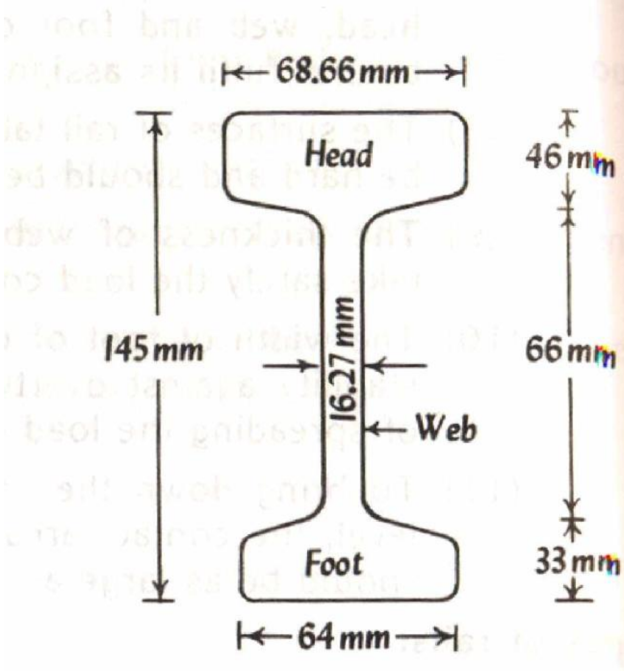
Double headed rail

- The double headed rails were made of wrought iron with le varying from 619 cm to 732 cm. Fig. shows a 49.60 k double headed rail.

Bull headed rails

- These rails consist of head, web and foot and are made of steel.

- The head is larger than the foot and the foot is designed only to properly hold the wooden keys with which the rails are secured to chairs.
- Thus the foot is designed only to furnish the necessary strength to the rail



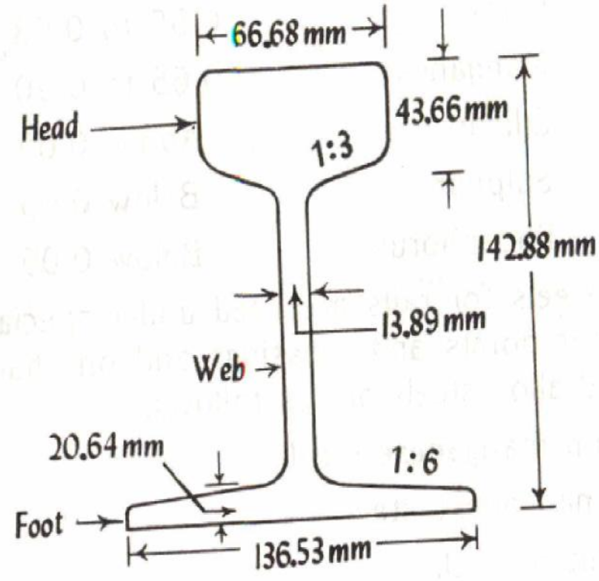
Bull headed rail

- The two cast iron chairs are required per each sleeper when these rails are adopted.
- The weight of standard rail of this type on British Railways on main lines is 47 kg per metre of length and it is 42 kg per metre of length on branch lines.
- The length of the rail is generally 18.29 metres. Fig. shows a 43.90 kg bull headed rail.

Flat footed rails

- In this type of rail, the foot is spread out to form a base.
- This form of rail has become so much so popular that at present about 90% of the railway track in the world is laid with this form of rails.
- Fig. Shows the standard rail of 45 R.B.S. on the India Railways.

- British railways have have introduced 54 kg/rn and 49 kg/rn flat footed rails instead of corresponding 47 kg/rn and 42 kg/rn bull headed



Flat footed rail

Coning of wheels

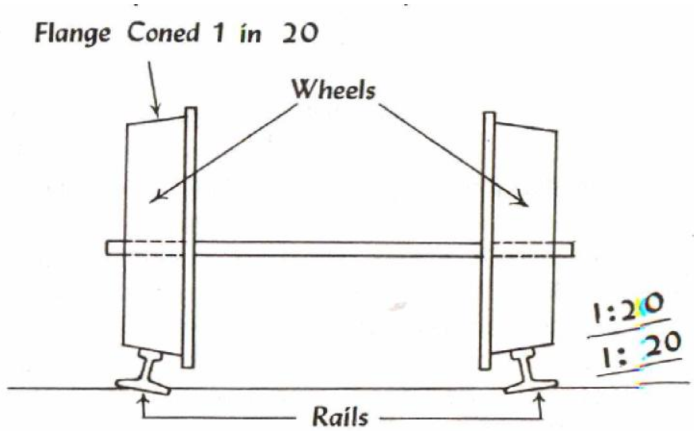
- The flanges of wheels are never made flat.
- But they are in the shape of a cone with a slope of about I in 20.
- As the wheels are set on the axle, there is some chance for lateral movement between the flanges of the wheels and the rails.
- Hence, with coning, the flanges would cause a slight but sudden shock to t sides of the rails.
- Thus the coning of wheels is mainly done t maintain the vehicle in the central position with respect to the track.
- The behaviour of coned wheels on straight and level track IS shown in fig.
- In this case, the flanges of wheels have equal circumference.
- But the situation is different when the wheels move along a curve as shown in fig.
- In this case, the outer rail to cover a greater distance than that of the inner rail.
- Also, as the vehicle has a tendency to move sideways towards the outer rail, the circumference of the flange of outer wheel will be greater than that of the inner wheel and this will help the outer wheel to cover a longer distance than the inner wheel.

Following are the disadvantages of the coning of wheels:

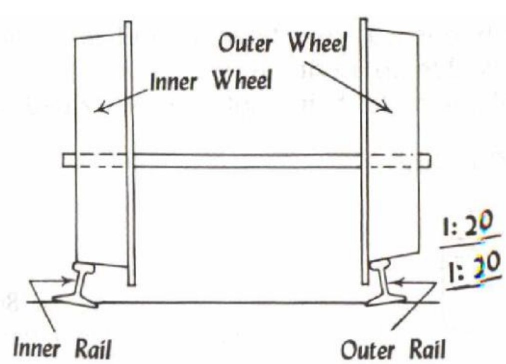
- The smooth riding is produced by the coning of wheels. But the pressure of the horizontal component near the inner edge of the rail has a tendency to wear the rail quickly.
- The horizontal component tends to turn the rail outwardly and hence the gauge is sometimes widened.
- If no base-plates are provided, the sleepers under the outer edge of the rail are damaged.

In order to minimize the above-mentioned disadvantages

- The tilting of rails is done, which means that the rails are not laid flat. But they are tilted inwards.
- The most common method adopted for tilting of rails is to use inclined base-plates as shown in fig.
- The slope of the base-plate is I in 20 which is also the slope of the coned surface of the wheel.



Behaviour of coned wheels on level track



Behaviour of coned wheels on curves

Following are the advantages of the tilting of rails:
(1) The tilting of rails maintains the gauge properly.
(2) The wear of the head of the rail is uniform due to tilting of rails.
(3) The tilting of rails increases the life of sleepers as well
as rails.

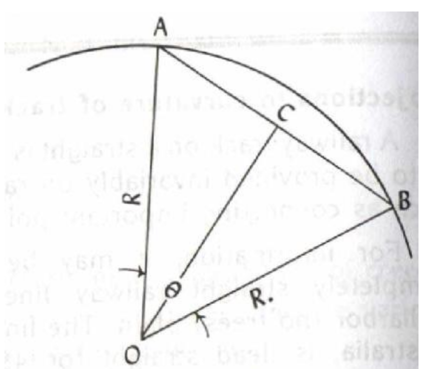
Curvature of Track

The main objections to the curvature can be summarized as follows:

- The working trains on the curvature are seriously affected and it results in restricted speed, limiting length of train and prevention of use of the heaviest types of locomotives.
- The maintenan1ce cost of track increases due to curvature of the track This is mainly due to increase in the tractive force, increase in the wear and tear of parts of track and increase in wear and tear of the equipment.
- The running of trains on curvature is not smooth.
- The danger of collision, derailment or other form of accident IS increased on curvature.

Designation of a curve:

- A simple curve is designated either by its degree or by its radius.
- The degree of a curve is the angle subtended at the centre by a chord of 30 m length.
- Thus, in fig, if AB = 30 m and angle AOB=6°, the curve is of I degree and with the same length of AB, if angle AOB= 6°, the curve is of 6 degrees.
- It can be easily understood that the greater the degree of curvature, the sharper wilt it be and consequently, the smaller will be its radius.
- It is very simple to establish the relationship between the radius of curvature and the degree of a curve.
- In fig. C is the centre of AB.



Designation of a curve

$$\sin\frac{\theta}{2} = \frac{BC}{OB} = \frac{AC}{AO} = \frac{15}{R}.$$

$$R = \frac{15}{\sin\frac{\theta}{2}} \ldots\ldots\ldots$$

- From equation (1), the radius of I degree curve works out to be equal to 1718.89 m
- But for practical purposes this can be taken as 1719 m.
- The radii of other degrees will be nearly inversely proportionate to the degree of curve..

$$R = \frac{1719}{\theta} \text{ m approximately.}$$

- If length of chord=20 m, $R = \frac{1146}{\theta}$

Types of curves and limiting radius or degree of curvature

- The curvature may be in the form of simple circular curves or compound and reverse curves or vertical curves.
- Except the transition curves, the railway curves are uniform in nature i.e. for any unit of length travelled round the curve, there is the same amount of change of direction.
- The only curve which satisfies this requirement is the circumference of the circle.
- The railway curves therefore are essentially circular curves or part of the circumference of a circle
- **A transition curve** is provided at the starting point of the circular curve to have constant rate of change of radial acceleration.

- The radius of transition curve varies from infinity at the junction with the straight to the radius of circular curve at the junction with the circular curve.
- **<u>The vertical curves</u>** are introduced in vertical plane in the form of a parabola.
- The vertical curves are necessary for smooth running of the vehicles on the track under the following circumstances:

(1) A rising gradient changes to a falling gradient or vice versa.
(2) A rising gradient or falling gradient is increased or decreased.

  - If vertical curves are not provided in such cases, there will be very bad lurching in the train and it will cause discomfort to the passengers and sometimes may even cause an accident.
  - The curves can be laid out on the ground by suitable method of surveying.
  - For the Indian railways, the vertical curves are provided at the junction of grades when the algebraic difference between the grades is equal to or more than 4 mm per m or 0.40 per cent.

<u>TRANSITION CURVE</u>

  - A transition curve is a type of curve which is introduced. in between a straight and a circular curve or between two branches of a compound curve.
  - It is a curve with varying radius and. is sometimes called the spiral or easement curve. It satisfies the. following objects:

(1) It creates smooth running and imparts comfort to the passengers.
(2) It helps in attaining the desired super gradually.
(3) There is a gradual increase in curvature of the track from, zero at the straight end to that of the circular curve at the junction with the circular curve.
(4) The chances of derailment are greatly decreased.

<u>Requirements of transition Curve</u>:

The essential requirements of an ideal transition curve are as follows:
(1) The transition curve should be tangential to the straight.
(2) The length of the transition curve should be worked in such a way that full super-elevation IS attained at junction between it and the circular curve.
(3) The rate of increase of curvature should be equal to the rate of increase of cant or super-elevation.
(4) The transition curve should join the circular arc tangentially or in other words, the curvature of the transition curve should conform with that of the circular curve.

Forms of transition curve:

- The various forms of transition curves are found out such as Euler's spiral, Froud's cubic parabola etc.
- The equation representing Froud's cubic parabola is as follows:

$$Y = \frac{X^3}{6RL}$$

where Y=Perpendicular offset of transition curve at a distance X from commencement of the curve

X=Distance of any point on the tangent from commencement of the curve

R=Radius of circular curve

L=Total length of transition curve

Length of transition curve

- The length of a transition curve is the centre-line length along the track between the starting point on the straight and the meeting point on the junction with the circular curve.
- For the Indian railways, this length is worked out by the following formulas:

(1) $L = 7.20\ e$

(2) $L = 0.073\ D \times V_{max}$

(3) $L = 0.073\ e \times V_{max}$

where L = Length of transition curve in m

e = Actual super-elevation or cant in cm

D = Cant deficiency for maximum speed in cm

V_{max} = Maximum speed in km p.h.

Shift:

- In order to fit the transition curve, the main circular curve is to be moved inwards by a certain distance
- This distance is termed as the shift and for a cubic parabola, it is worked out by applying the following formula:

$$S = \frac{L^2}{24R}$$

where

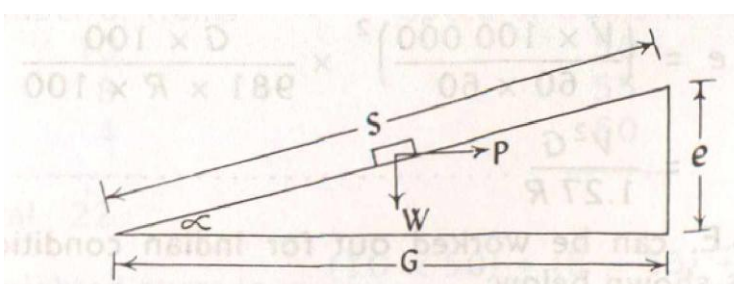
S = Shift

L = Length of transition curve

R = Radius of circular curve.

Super-elevation or cant:

- when a train is running along a straight track, the heads of the rails must be kept absolutely at the same level.
- But when it is moving on a curved path, it has a constant radial acceleration which produces centrifugal force. In order to counteract this force, the outer rail of the track is raised slightly higher than the inner rail.
- This is known as the **super-elevation or cant** and it serves the following purposes:
    - It ensures smooth and safe movements of passengers and goods on the track.
    - It introduces the centripetal force to counteract the effect of the centrifugal force and hence the faster movement of trains on curves can safely be permitted.
    - It prevents derailment and reduces the creep as well as side wear of rails.
    - It provides equal distribution of wheel loads on two rails and hence there is no tendency of track to move out of position.
    - It results in the decrease of maintenance cost of the track.



Super-elevation

- It is evident that the rotation will take place about the vertical axis and sin the centrifugal force acts at right angles to the axis of rotation, its direction will be horizontal.

Let, W=Weight of moving train

v= Velocity in metres per second

P=Centrifugal force acting on the vehicle through its centre of gravity

g= Acceleration due to gravity in m/sec^2

R=Radius of curve in m

C=Gauge of track in m

e=Super-elevation in cm

I= Angle of inclination

S=Length of inclined surface.

$$P = \frac{Wv^2}{gR}$$

$$\frac{Wv^2}{gR} \times \frac{G}{S} = W \times \frac{e}{S}$$

$$e = \frac{v^2}{gR} \times G$$

V = Velocity in km per hour

$$e = \left(\frac{V \times 100\,000}{60 \times 60}\right)^2 \times \frac{G \times 100}{981 \times R \times 100}$$

$$= \frac{V^2 G}{1.27\,R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

for B.G.

$$S.E. = \frac{V^2 \times 1.676}{1.27 \times R} = 1.315 \frac{V^2}{R}.$$

for M.G.

$$S.E. = \frac{V^2 \times 1.00}{1.27 \times R} = 0.80 \frac{V^2}{R}.$$

for N.G.

$$S.E. = \frac{V^2 \times 0.762}{1.27 \times R} = 0.60 \frac{V^2}{R}.$$

Factors affecting super-elevation:

The calculated value of super-elevation is affected by the following factors:

Frictional resistance:

The frictional resistance between the wheel and the rails will have some effect on the amount of super-elevation.

Coning of wheels:

The surface of the wheels will ‘not be cylindrical. But it will be inclined to horizontal due to coning of wheels.

Hence the motion of the train will not be in a horizontal plane.

Body of the vehicle:

In the derivation of the formula for the super-elevation, the body of the vehicle is assumed to be rigid. But in actual practice, it is provided with compressive springs in order to minimize the effect of impact. This factor will considerably alter the calculated value of super-elevation.

Weighted average:

- The super-elevation can be calculated only for a particular speed whereas in actual practice, different trains at different speeds will be using the curvature with super-elevation.
- Hence the super-elevation should be such as to accommodate these variations of speed from time to time.
- For this purpose, a speed is worked out depending on the number of trains running at different speeds.
- This speed is known as the **weighted average**.

Grade compensation on curves:

- The ruling gradient is defined as the maximum gradient to which a track may be laid in a particular section.
- Now, if a curve is situated on a ruling gradient, the total resistance would be the addition of resistance due to curvature and the resistance due to ruling gradient.
- This will increase the resistance which is worked out on the consideration of gradient only.
- In order to avoid resistances beyond a definite limit, the gradients on curves are reduced and such reduction is known as the grade compensation on curves.
- There are various factors affecting curve resistance.
- But it is taken as a percentage per degree of curve.
- the Indian railways have adopted the values of grade compensation on curves as 0.04 i4 per cent per degree of curve on B.G., 0.03 per cent per degree of curve on MG. and 0.02 per cent per degree of curve on N.G.

If the ruling gradient is 1 in 200 on a particular section of B.G. and if a curve of 4 degrees is situated on this ruling gradient, what should be the actual ruling gradient?

Solution:

Assuming grade compensation on B.G. as equal to 0.04 per cent per degree of curve,

compensation allowed = (0.04×4) = 0.16 per cent.

Now, 1 in 200 = 0.50 %

$\therefore$ actual gradient allowed = $(0.50 - 0.16)$ = 0.34 per cent

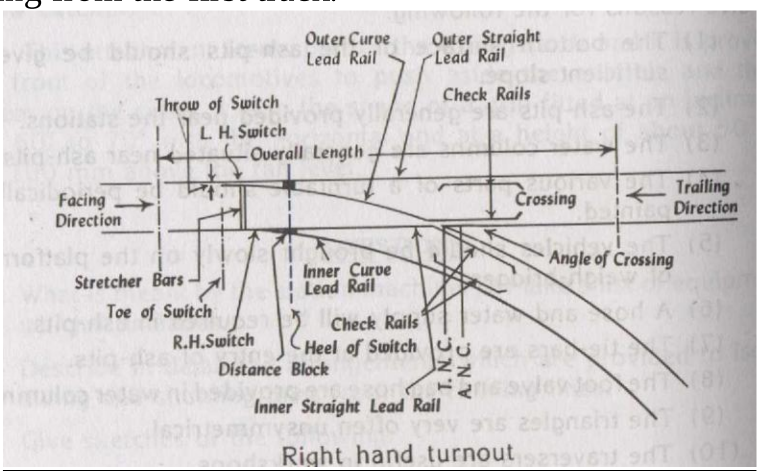
or 1 in 294 will be the ruling gradient for the curve. *Ans.*

UNIT-2
RAILWAY TRACK CONSTRUCTION, MAINTENANCE AND OPERATION

POINTS AND CROSSINGS

Purpose for providing points and crossings:

- The point and crossing are the names given to the arrangement which diverts the train from one track to another, either parallel to or diverging from the first track.



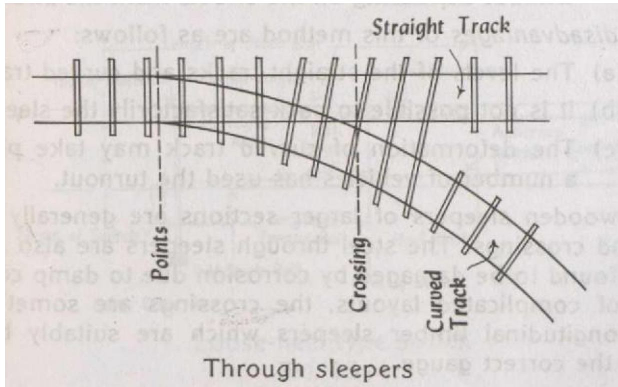
- A switch consists of a tongue rail and a stock rail.
- The tongue rails are made of thinner sections at the toe of the switch.
- The tongue rails are supported on sliding plates and each pair of tongue rail is connected by stretcher bars near the toe of switch so that ho the tongue rails move through the same distance or gap. This g is known as the throw of switch.
- A heel block or a distance block and fish-plates are provided at the heel of switch to connect tongue rail with stock rail.
- A set of switches consists of a left hand switch and a right hand switch.
- A set of switches is known as the points.

Sleepers laid for points and crossings:

Following are the two methods of laying the sleepers below the points and crossings:

(1) Through sleepers

(2) Interlaced sleepers.
Each of the above method of laying the sleepers will now be briefly discussed.

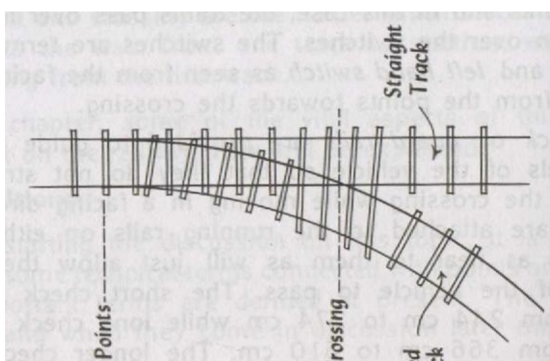


<u>Through sleepers</u> :

- The through sleepers are nearly laid for points and crossings and they are provided in the overall length of points and crossings.
- The maintain several rails at the same level and it is alignment of the curved track in relation to the in this case, the long sleepers will be required.

<u>Interlaced Sleepers</u>:

- Where there is shortage of long sleepers, the interlacing of sleepers is done between the switches and the crossing as shown in fig .through sleepers possible to fix the straight track. But



<u>The advantages of this method are as follows:</u>
(a) Some cant or super-elevation can be given to the outer curve lead rail.
(b) The curved track can be adjusted to a very nice curve without depending on the offsets from the straight track

The disadvantages of this method are as follows:
(a) The levels of the straight tracks and curved tracks vary
(b) It is not possible to pack satisfactorily the sleepers
(c) The deformation of curved track may take place after a number of vehicles has used the turnout.

Steel for points and crossings:

- The special steel is used for the switches and crossings as there will be more wear and tear at these points due to high speeds heavy axle loads
- The alloy steels are used for this purpose.
- The common alloy steels are medium manganese steel and high manganese steel.
- The former is used where the traffic is light while the latter is used where the traffic is heavy.
- The chrome steel has been found useless for points and crossings it is not suitable for repair by welding.

Switches

Following are the two types of switches:

- Stub switch
- Split switch.

Each of the above type of switch will now be described.

Stub switch:

- This is the earliest form of switch, No separate tongue rails are provided in stub switch.
- But some portion of the main tracks is moved from side to side. This type of switch has many objectionable features and it has been practically replaced by the split switch which is now universally adopted.

Split switch:

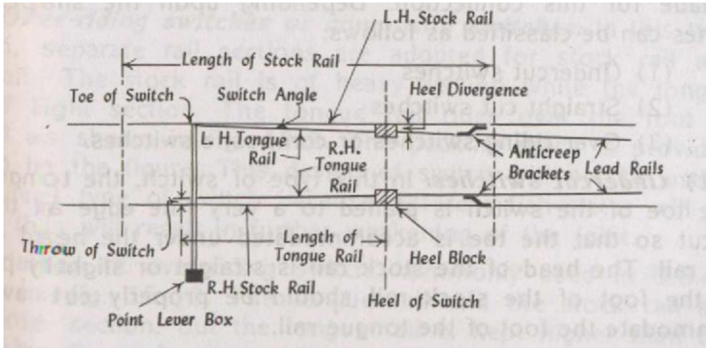
A split switch essentially consists of two parts:
(1) a stock rail and
(2) a tongue rail.

The split switches are of two types:
(a) Loose-heel type or articulated type switch
(b) Fixed-heel type or spring switch or flexible switch.

Loose-heel type or articulated type switch:

- In this type of switch, the fish-plates join lead rails to the tongue rail of the switch. The two front bolts are kept loose to allow for the throw of the switch.

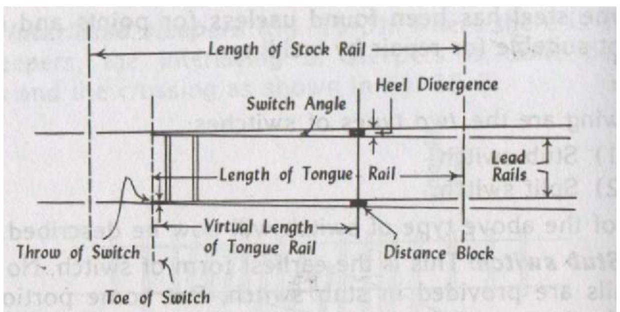
- Hence the heel joint becomes weak shows a typical layout of this type of switch.
- The point lever box, heel block and anti-creep brackets are provided as shown in the figure.



Loose-heel type switch

<u>Fixed-heel type or spring switch or flexible switch</u>:

- In order to overcome the weakness of the loose-heel type switch, the fixed-heel type has been found out.



Fixed-heel type switch

- In this type of switch, the tongue rail is held in its position with stock rail at the virtual heel by means of a heel or distance blocks, bolts and nuts.
- The switch can be hand-operated or can be worked by a rod from a lever frame.
- The lead is worked out in the usual way. But it is measured from the centre of the heel block. Fig. shows a typical layout of this type of switch.

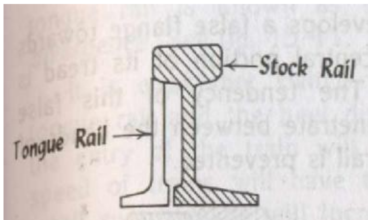
<u>Shapes of switches</u>:

Depending upon the shapes; the switches can be classified as follows:

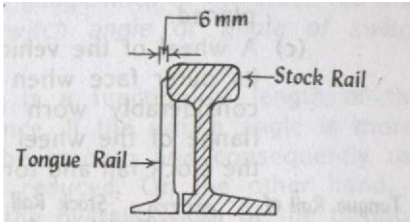
- Undercut switches
- Straight cut switches
- Over-riding switches or composite switches.

Undercut switches:

- In this type of switch, the tongue rail at the toe of the switch is planed to a very fine edge at the top and cut so that the toe is accommodated under the head of the stock rail.
- The head of the stock rail is straight or slightly planed
- Also the foot of the stock rail should be properly cut away to accommodate the foot of the tongue rail.
- Fig. shows the old design of this type of switch and fig. shows the modified form of undercut switch which now commonly used.
- In the modified section, only about half the web of tongue rail is below the head of stock rail and width of top of tongue rail is increased.
- Thus the tendency of splitting of 0 rail is considerably reduced. On the whole, the perf0t'man of undercut switches is not satisfactory.



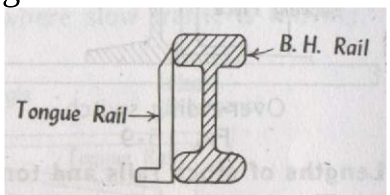
Old undercut switch



Modified undercut switch

Straight cut switches:

- This type of switch is known as the straight cut switch because the tongue rail is kept straight in line with the stock rail as shown in fig.
- Thus the thickness of the toe of tongue rail becomes thick and thereby its strength is increased



Straight cut switch

- For this type of switch, the stock rail is joggled by an amount equal to the thickness of the tongue at 13 mm from the toe.
- The joggled length is usually 152 mm.
- The gauge will increase over the joggled length of the stock rail.

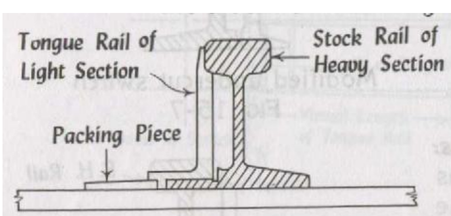
- Hence it is usual practice lo provide straight cut switches for facing points and to provide undercut switches for trailing points.
- This design of switch is useful or B.H. rails and hence it is still adopted on the British Railways.

<u>Over-riding switches or composite switches</u>:

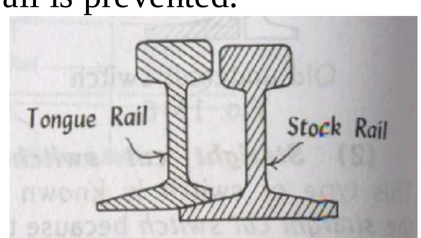
- In this type of switch, separate rail sections are adopted for stock rail and tongue rail.
- The stock rail is of heavy section while the tongue rail is of light section.
- The tongue rail rides over the foot of Stock rail as shown in fig.
- The packing piece is provided is shown in the figure.
- This design of switch will not be useful in loose type of switch because different fish-plates will be used and this will result in further weakening of the joint.
- A variation of over-riding switch, commonly used in U.S.A., in fig.
- The tongue rail and the stock rail are the same section.
- But the tongue rail is kept higher than the 5 rail by 6 mm for part of its length.
- The difference in height be by putting special machined bearing plates behind the
- There is no doubt that some oscillation is bound to be delveloped due to rising of tongue rail, But several other advantages med for this type of switch are as follows:

(a) The tongue rail is supported on the flange of the stock rail
(b) The stock rail remains of maximum section as it is ot planed.
(c) A wheel of the vehicle develops a false flange towards its outer face when the central portion of its tread considerably worn out.

The tendency of this false flange of the wheel to penetrate between the heads or the stock rail and tongue rail is prevented.



Over-riding switch



Modified over-riding switch

Crossings:

- It is a device which is provided at the intersection of two rails so as to permit the vehicles moving along one of the track to pass across the other track.
- The crossings may be built-up, cast at place or a combination of the two.
- The built-up crossings are very common.
- But as they are not very rigid, they are not suitable for fast and heavy traffic.
- they can be easily and cheaply repaired or reconditioned
- The cast crossings are very much suitable on fast and heavy traffic

Lines

- There are no bolts to be tightened and the crossing practically undeformable.
- The initial cost is high. But it requires ye little maintenance.
- In the combined type, a cast steel ØSC provided to two wing rail pieces

Types of crossings:

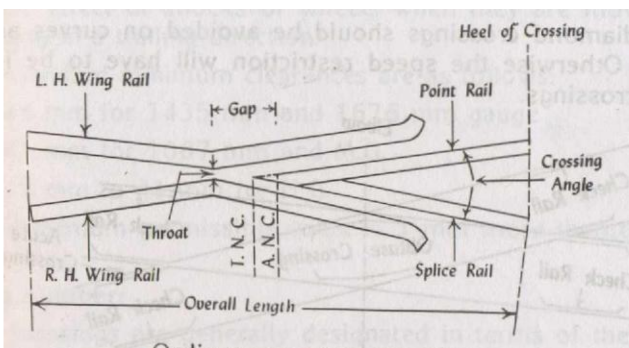
Following are the two types of crossings

(1) Ordinary or acute crossing

(2) Double or obtuse crossing.

Ordinary or acute crossing

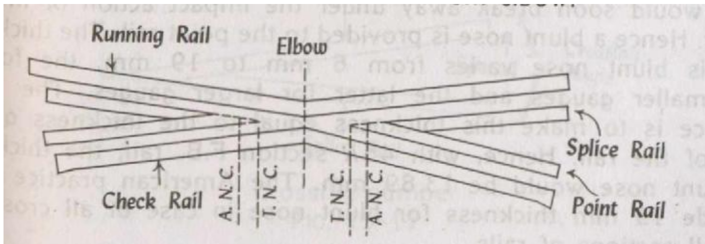
- Fig shows a typical ordinary or acute built-up crossing.
- All the measurements are taken from the theoretical nose of crossing.



Ordinary or acute crossing

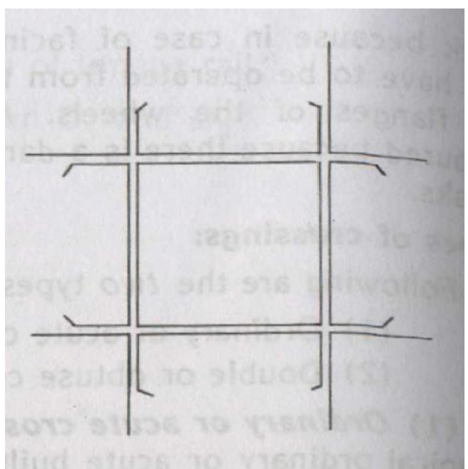
Double or obtuse crossing

- A double crossing two noses and is used in the formation of diamonds.
- The gauge lines intersect at elbow as shown in fig. and all measurements locating the crossing are to be taken from elbow.

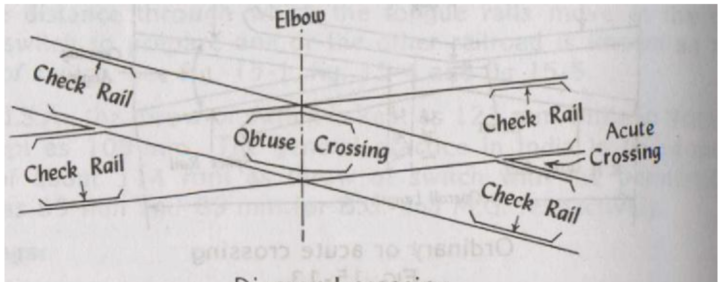


Double crossing

- Diamond crossings may be situated on straight track or curved track.
- They may occur between similar tracks or unsimilar tracks
- When the angle becomes 90 it is known as the **square crossing** as shown in fig. and it should be avoided as far as possible because there is rapid wear of the crossings and damage to the rolling stock on account of the heavy impact.
- When one track crosses another at an angle, as shown in fig. a diamond comprising of two acute crossings and two obtuse crossings is formed.
- For all diamond crossings, the gauge is kept 3 mm tight for the steady running of vehicles on the track.


Square crossing

➢ The diamond crossings should be avoided on curves as far as possible. Otherwise the speed restriction will have to be imposed on such crossings.



Diamond crossing

Crossing clearance:

➢ The distance between the wing rail and crossing rail is known as the crossing clearance.

➢ Crossing clearance is found to be slightly greater due to the fact that it is not possible to bend the wing rails to a fine point at this spot.

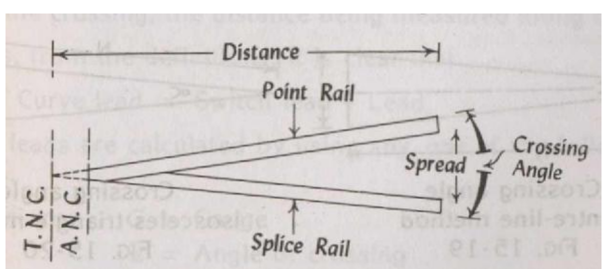
➢ This fact is sometimes deliberately included in the design of the crossing to reduce the effect of shocks of wheels when they are moving over the crossing in a trailing direction.

➢ The standard minimum clearances are as follows:

- ❖ 44 mm for 1435 mm and 1676 mm gauge
- ❖ 41 mm for 1067 mm and M.G.
- ❖ 38 mm to 41 mm for N.G.

Crossing number:

- The crossings are generally designated in terms of the distance required in spreading the point and splice rails by 305 mm
- The spread s measured between the gauge faces of the rails and the distance is measured from theoretical nose of crossing as shown in fig.



Crossing number

➢ The crossing numbers in common use on the Indian railways are 1 in 8 1/2, 1 in 12, 1 in 12 and I in 20.

Crossing angle:

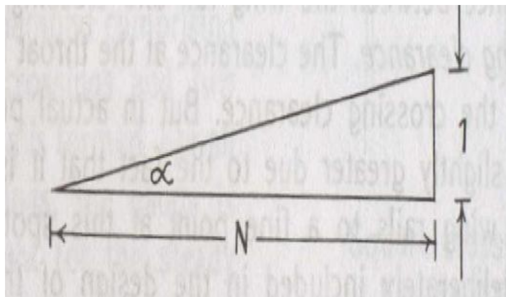
➢ The angle which is formed between the gauge faces of the Vee is known as the crossing angle.

Following are the three method of calculating the angle of crossing:

Notations Ị = angle of crossing and N = crossing number

Right angle or Cole's method:

In this case, a right angle triangle is used as shown in fig



Crossing angle—right angle method

Then, $\tan\alpha = \frac{1}{N}$

or $\cot\alpha = N.$

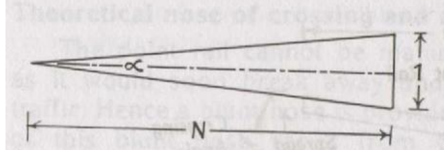
This is the standard method adopted on the Indian railways.

Centre-line method:

➢ In this case, the measurement is taken along a line bisecting the crossing angle as shown in fig.

Then, $\tan\frac{\alpha}{2} = \frac{\frac{1}{2}}{N} = \frac{1}{2N}$

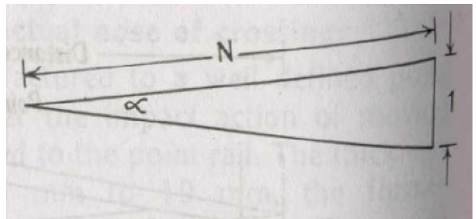
$\therefore \cot\frac{\alpha}{2} = 2N.$



Crossing angle
centre-line method

Isosceles triangle method:

➢ In this case, the measurement is taken along one of the sides of an isosceles triangle as shown in fig.



Crossing angle
isosceles triangle method

$$\sin\frac{\alpha}{2} = \frac{\frac{1}{2}}{N} = \frac{1}{2N}$$

$$\operatorname{cosec}\frac{\alpha}{2} = 2N.$$

- This method used for layouts of tramways

Laying of points and crossings:

The work of laying points and crossings may fall under one of the two following categories:

- Where there is no traffic interruption as in case of a new turnout:

In this case, the work may be carried out in a thorough manner with all the usual precautions

- Under traffic where the line is available for a few hours only:

In such cases, the work of laying points and crossings can be carried out by any one of the following three ways:

- The connections may be built-up at site of work. This method is useful for ordinary turnouts and cross-overs.
- The connection may be laid out on an adjoining plot of field and then it may be rolled in position when line is available for doing work. This method is useful when sufficient time is not obtained due to heavy traffic on the line.
- (c) The connection may be prepared at workshop or depot and then, after carefully marking positions of the various parts, it is dismantled carried and built-up again at site of work. This method is useful for very complicated layouts.

Maintenance of points and crossings:

Following items should be carefully attended:

- If there is any creep, it should be removed. The anticreep brackets should be provided behind the heel of switch and the wing rail of crossing.
- The sleepers should be checked periodically and if they have moved, they should be correctly spaced.

- All Loose bolts should be tightened. For loose heel type heel block, the tongue rail bolts are kept loose and lead rail bolts are kept tight. For fixed heel type heel block:, all bolts are kept tight.
- All sleepers should be thoroughly packed.
- The drainage arrangements should be properly made for points and crossings.
- The screening of ballast under points and crossings should be carried out at regular intervals.
- The gauge of the track should be checked and it should be exact at all places except at the toe where it should be a little slack.
- The clearances between check rail, tongue rail and wing rail should be checked and rectified, if necessary.
- It should be seen that the interlocking connection is clear of ballast and all such connections must fit tightly.
- The fouling marks should be cleaned and painted, required.
- The alignment of points and crossings should be checked and rectified, if necessary.
  - The lubrication to various components. of the points and crossings should be done periodically.

Signalling

Objects of signalling:

The main objects of signalling along a track line are as follows:

- to prevent a running train from coming into contact with another train or obstruction and thus to provide safety to th passengers, the staff and the rolling stock;
- to maintain a safe distance between trains running on the' same line in the same direction and thereby to facilitate the flow of traffic and to increase the carrying capacity of the track**;**
- to provide protection to trains at converging junctions and to give directional indication at diverging junctions;
- to provide facilities for carrying out shunting operations, safely and efficiently; and
- to allow the trains to run at restricted speed during th maintenance and repairs of the track.

Types of signals:

The various types of signals can be classified as follows:

(1) Classification according to function
(2) Classification according to location
(3) Special signals.

Classification according to function:

According to this classification, the signals are classified as follows:

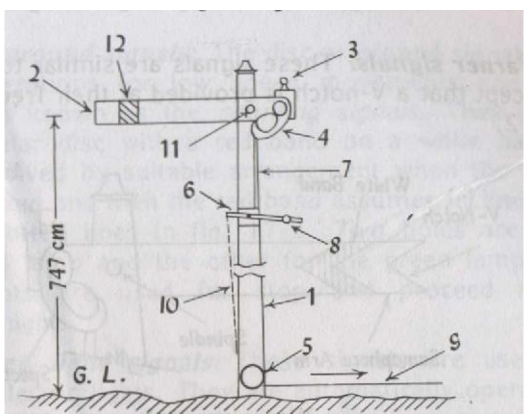
(a) Stop signals or semaphore type signals
(b) Warner signals
(c) Disc or ground signals
(d) Coloured light signals.

(a) **Stop signals or semaphore type signals**:

- A typical section of the ordinary type of semaphore signal is shown in fig.
- The list of parts is given below:

The most important requirement in this type of signal is that if anything goes wrong with the apparatus, the signal should show the stop position. The signal mechanism should therefore be so arranged that this is the normal position of the signal.

(1)Signal post	(5)Pulley or drum	(9) Signal wire
(2)Semaphore arm	(6)Cam and fulcrum	(10)Chain
(3)Lamp	(7)Crank rod	(11) Spectacles
(4)Weight lever	(8) Spindle	(12) White band.



Essential features:

The essential features of a semaphore signal are as follows:

- A horizontal semaphore arm is fixed to a vertical post and is provided at its backside with suitable arrangements to indicate red and green lights.

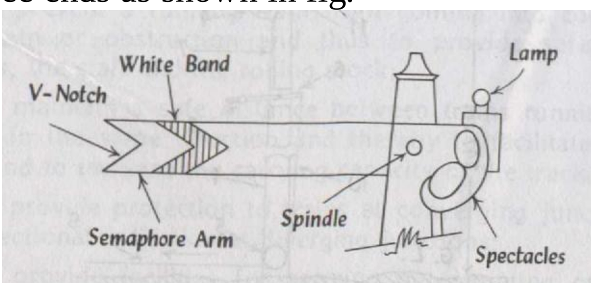
- It is about 1676 mm long and 356 mm wide and is designed, in such a way that its weight at the smaller end is just sufficient to make it stand in the horizontal position ordinarily.
- In India, the semaphore signal is placed with the vertical post on the left hand side of the direction of motion and the semaphore arm projects towards the track for which it gives signals.
- The side of the arm facing the driver is painted white with vertical black band. The height of centre of arm above ground level is about 7470 mm.
- A crank or any other device which is fixed on a horizontal pin on which the semaphore is also fixed so that they move together.
- A crank rod to move the crank is provided.
- A weighted lever revolving about a pin is provided. To one end of the lever is attached a counterweight and the crank rod is attached through a cam to the lever.
- To the other end of the lever is attached the signal wire which is taken down over pulleys to the signal cabin.
- A ladder is provided for the physical connection between the semaphore arm and the ground level.

Working of semaphore signal:

- The semaphore arm can take up two positions, namely, horizontal and inclined.
- The normal position of the signal is horizontal and it can be lowered by pulling the wire from the signal cabin.
- When the signal is in horizontal position, it is said to be in on position which indicates stop or danger.
- When it is lowered at an angle of 40° to 60°, it is said to be in off position which indicates proceed.
- The corresponding indications at night are, a red light for danger and a green light for proceed.

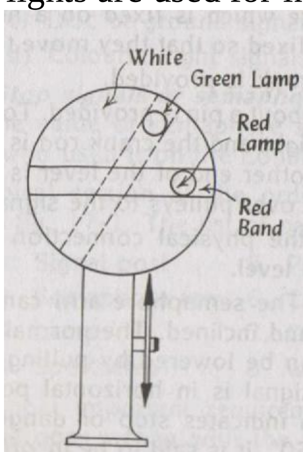
Warner signals:

These signals are similar to the semaphore signals except that a V-notch is provided at their free ends as shown in fig.

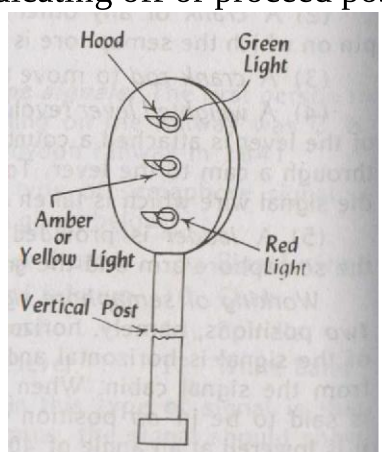


Warner signal

- This signal is placed ahead of the ordinary semaphore signal and its main function is to warn the driver,
- It is often fixed on the same vertical post carrying outer signal. When the warner signal is horizontal or in on position, it indicates that the signal ahead is in stop or danger position.
- Thus it gives guidance to the driver of the train regarding the conditions ahead and he can proceed with the train beyond the warner signal, even though it is in on position with precaution.
- When the warner signal is in the inclined position, it signifies that the signal ahead is in off position and hence the driver can proceed at speed without any danger.
- On some Indian railways, the warner signals are provided with yellow lights instead of red lights for corresponding indications at night.
- The green lights are used for indicating off or proceed position.



Disc signal



Coloured light signal

<u>Disc or ground signals</u>:

- The disc or ground signals are used shunting operations for low speed movements and they are even known as the shunting signals.
- They are in the form of a circular disc with a red band on a white background.
- The disc is revolved by suitable arrangement when the signal has to indicate proceed and then the red band assumes’ inclined position as shown by dotted lines in fig.
- Two holes are provided, one for the red lamp and the other for the green lamp.
- The red and green lights are used for stop and proceed indications respectively at night.

Coloured light signals:

- These signals are used to give indications by electric lights.
- They are automatically operated.
- They generally consist of three lights fixed on a vertical post. The height of the vertical post is kept sufficient so as to be in line with driver's eye-level.
- The special lenses and hoods are provided to protect the lights so that they can be seen even in sunlight.
- In India, the coloured light signals are used on urban and sub-urban sections with heavy traffic.

Working of coloured light signals:

- The red light shows stop, yellow or amber light shows proceed cautiously and green light indicates proceed.
- Normally the signal remains in off or proceed position and as soon as a train enters a section, it automatically changes to stop or on position.
- This is the main difference of coloured light signals with ordinary semaphore type signals in which case the signal normally remains in the stop or on position.
- It may be mentioned that these three colours red, yellow and green are used almost throughout the world today and give the driver the same basic message wherever they are used.

Classification according to location:

The signals are classified as follows depending upon their location:

(a)Outer signal

(b) Home signal

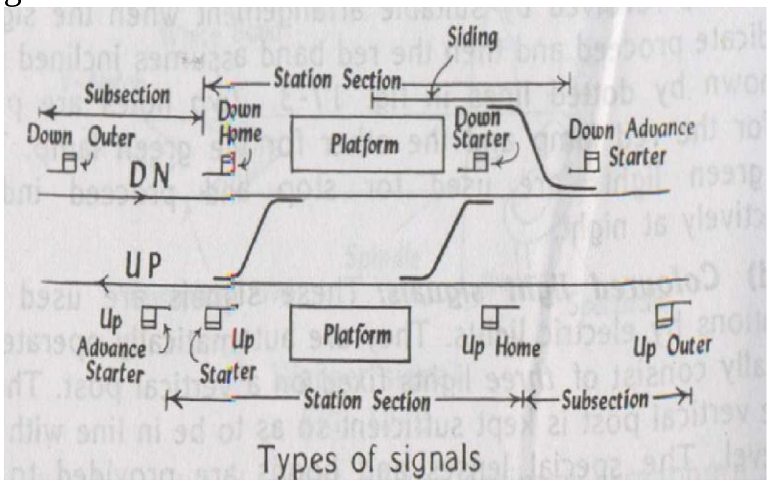
(c) Starter signal

(d) Advance starter signal

Outersignal:

- A certain distance is required for train in motion to be brought to a halt and this depends on the weight of the train, brake power of the locomotive, gradient at the site and the speed of the train.
- For the maximum allowable speed in India, this distance is found to be nearly equal to 0.54 km for 5.0. and 0.40 km for MG.
- Therefore the first signal is provided at this distance beyond the station limit and this signal is known as the outer signal.
- In the stop position, it indicates that the driver must bring his train to stop at a distance of about 9 m before the outer signal and then proceed to the home signal with caution.

- In the proceed position it indicates that the home signal is also in the proceed position and the driver can take the train at speed without any danger.



Home signal:

- This signal is provided exactly at the station limit and its main function is to protect the stations and Junction;.
- The permission to enter the platform is given by the operation of home signal.
- The maximum unprotected distance between the home signal and the points it is intended to protect is specified as l80m.
- If this distance is more, suitable means such as track circuits, locking bars, etc. should invariably be provided to protect the track.

Starter signal:

- This signal is provided on the forward end of the platform and it controls the movements of the trains as they leave the stations.
- No train can leave the platform unless the starting signal is lowered.

Advance starter signal

- This signal is provided to carry out shunting operation within its protection.
- These signals are in the form of disc or ground signals, dwarf semaphores or a other approved form with small lights.
- It should be noted the sufficient space should be kept between the signals and t cross-overs or sidings so as to accommodate the maximum like length of the train.

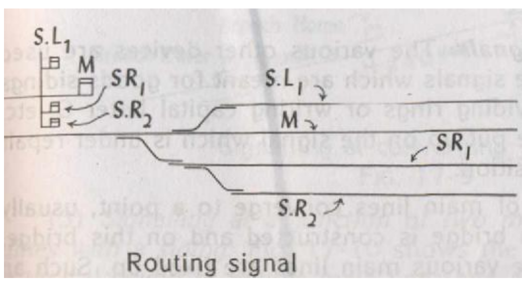
Special signals:

Following are some of the special types of signals:

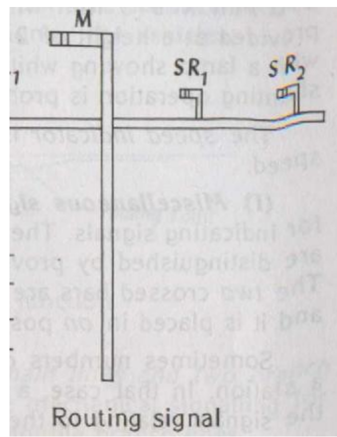
- Routing signals
- Repeating signals
- Co-acting signals
- Calling-on signals
- Indicators
- Miscellaneous signals.

Routing signals:

- When various signals for main and branch lines are fixed on the same vertical post, they are known as the routing sign as shown in fig.
- Generally the signal for the main line is kept at higher level than that for the branch line.



Routing signal



Routing signal

Repeating signals:

- The repeating signals are used to repeat the information of main signals when vision of main signals obstructed due to some structures.
- They are also necessary when signals are situated on curves near the station.
- Thus they are provided on separate posts to convey the information of the signals ahead to the driver.

Co-acting signals:

- When the sight of main signal is not continuously visible because of a tunnel or a bridge or due to 0 other reasons, a duplicate signal is provided on the same post at lower level.

- Such a duplicate signal is known as a co-acting s and it works together with main signal so as merely to repeat the Indic of main signal.

Calling-on signals:

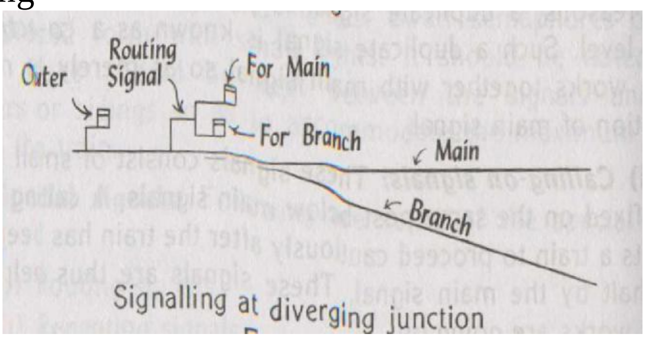
- These signals consist of small and 5 arms fixed on the same post below main signals.
- A calling-on signal permits a train to proceed cautiously after the train has been brought to a halt by the main signal.
- These signals are thus helpful when repair works are going on.

Indicators:

- These signals are provided to furnish special formation to the drivers.
- They are painted in black letters or figures on a yellow background.
- The whistle indicator consists of 610 mm square board with 5 mm high letter W. It is provided at a height of 2130 mm from the rail level.

Typical layouts:

- Signalling at diverging Junction
- Signalling at converging junction
- Signalling at a junction of two main lines and two branch lines with a siding



Signalling at diverging junction:

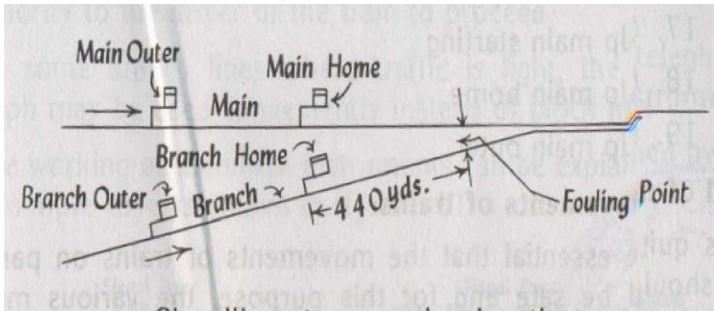
- Fig shows a simple junction with signals arranged relatively to the two routes
- The routing signal is provided as shown in the figure near the facing points outer signal is provided which may be of semaphore or warner type.

Signalling at converging junction:

- Fig. the most simple arrangement of the signals at converging junction.
- In such a case, the home signal for branch line would be provided at some arbitrary distance such as about 402 in

from the fouling point and separate outer signals for main and branch lines are provided.

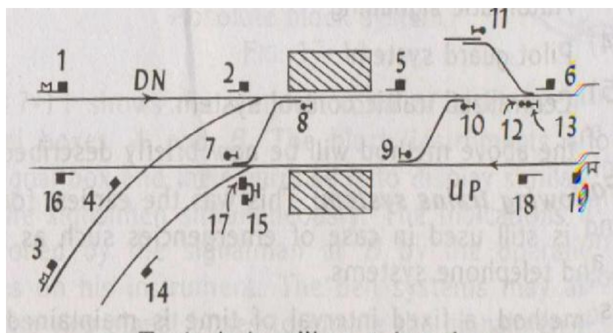
- The term fouling point is applied to the minimum safed between two converging lines so as to avoid collision of the vehicles.



Signalling at converging junction

Signalling at a junction of two main lines and two branch lines with a siding:

- Fig. shows the mechanical signalling for a typical layout of double main lines and double branch lines.



Typical signalling at junction

The numbers shown in fig signify the following signals:

1. Down main outer
2. Down main home
3. Down branch outer
4. Down branch home
5. Down main starting
6. Down main advance starting
7. Disc signal for up line to down platform
8. Disc signal for down platform to up line
9. Disc signal for up platform to down line
10. Disc signal for down line to up platform
11. Disc signal for siding to down line
12. Disc signal for no. 10
13. Disc signal for down line to siding
14. Up branch advance starting

15. Up branch starting
16. Up main advance starting
17. Up main starting
18. Up main home
19. Up main outer.

Automatic signalling:

- In order to avoid accidents due to negligence on the part of human beings, the automatic signalling has been found out.
- In this system, the signals are operated by trains themselves.
- An electric current is conveyed through the track when a train occupies that particular track and this current puts the signal at danger position until the train has gone far ahead so as to require no further protection.
- the electricity is transmitted to an electric locomotive either through overhead lines or third rail.
- The former is known as a catenary system and the locomotive obtains the current through a retractable collecting device known as a pantograph.
- In the latter case, a metal contact shoe which slides along the charged third rail is provided outside the running rails and electric current is transmitted through this metal shoe.
- Suitable electric fittings are attached to the wheel brakes of the locomotives.
- In case a driver of the train fails to take note of a signal in danger position these brakes are automatically applied.
- On the other hand, if the signal is in off position, the brakes will not function automatically
- The use of automatic signalling is increasing gradually and its future seems to be extremely bright due to the following stages
  - ❖ The number of signalmen required is less and hence the operating costs are reduced.
  - ❖ As human factor is eliminated, the value of factor of safety is creased.
  - ❖ There is considerable increase in the capacity of the line due to the fact that no time is wasted in exchanging messages as in case of absolute block system and the signals are automatically released as soon as the trains pass the clearance point.
  - ❖ This will also result into less number of locomotives and the vehicles required to handle a given traffic.

- ❖ No signal boxes and other equipments are required resulting in further saving of the costs.
- ❖ When the current fails, the arrangements are made so that all the signals return to danger position and thus the failure of automatic apparatus will not result in severe accidents.
- ❖ But at the most, it may bring all the trains at rest and thereby cause some delay and inconvenience.

Pilot guard system:

This system is used only on certain occasions such as:

- ❖ breakdown of telephone and telegraph system on a single line; and
- ❖ one track of a double line being out of order.
- ❖ In this system, a pilot guard proceeds by one train to the station ahead and then he returns by a train running in the opposite direction.
- ❖ No other train is allowed to move from the station till the pilot guard returns with the train from opposite direction.
- ❖ The pilot guard then again proceeds with a train in the same direction and the process is repeated.

Centralized traffic control system:

- ❖ In this system, a central control room is provided from which the points and signals are operated.
- ❖ The signal cabins are not required.
- ❖ The points and signals are suitably interlocked and an illuminated diagram is provided in the control room to study the movements of the trains.
- ❖ This system is briefly known as the CTC system
- ❖ In CTC system, the controller arranges for all crossings and Overtaking of goods and passenger trains.
- ❖ The drivers of the trains are supposed merely to respect the indications given by the signals prior to and near the point of execution.

Interlocking

Definition:

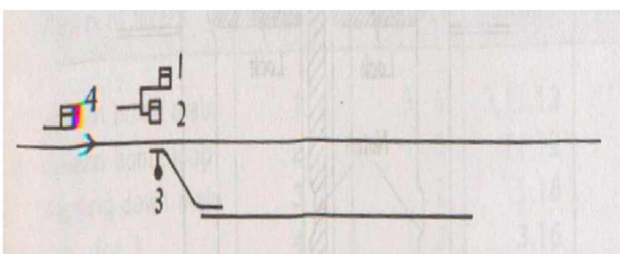
- ❖ The interlocking is defined as the mechanical relationships established between various levers operating the signals and the points through mechanical or electrical agencies such that contrary effects are not at all possible in the working of the signal mechanism.

Following are the three methods of interlocking:

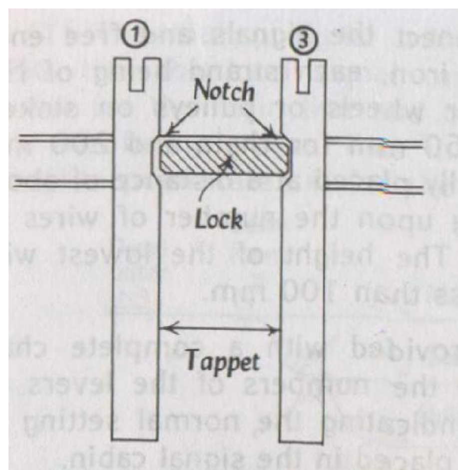
- Tappets and locks system
- Key system
- Route relay system.

Tappets and locks system:

- This method is useful when levers are to be interlocked so as to prevent the conflicting rnovements
- The tappets are of steel and normally of section 38 mm x 16 mm. They are attached to the levers and they have suitably shaped recesses and notches in them.
- The locks are also of steel and they have got the shapes which suit the recesses in the tappets.
- The locks move at right angles to the tappets. In order to illustrate the working of this method, a very Simple case, as shown in fig. will be considered.



Tappets and locks system



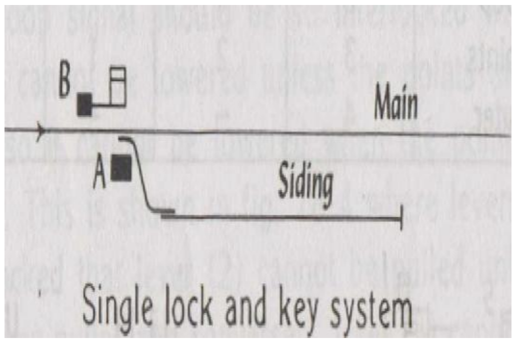
Tappets and locks system

Key system:

- This is the simplest method of interlocking and is used on many small stations in India.
- The key locks in one form or another are manipulated in this system. Sometimes this is also known as the indirect interlocking.
- The system that is commonly adopted for the working of this system is the Annets lock and key system.
- It may be single key system or double key system.

Single lock and key system:

- The principle of this system is to provide two locks which are worked by a single key.
- The withdrawal of the key locks the signal in the horizontal position and the points in the normal setting for the main line.
- A and B are two locks which are operated by a single key. Now to lower the signal, the key is inserted and turned in the lock B.
- This releases the signal. When the signal is lowered, it prevents the ey from being withdrawn.

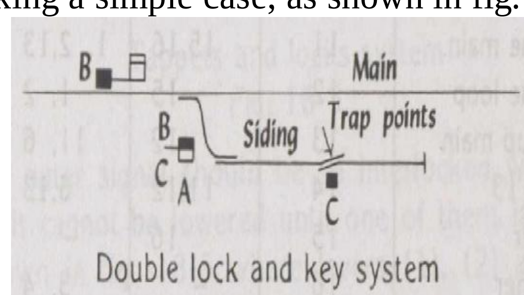


Single lock and key system

- Hence, when the signal is lowered, the points are correctly set for the main line.
- Similarly, if the siding is to be used, the key is withdrawn from the lock B after resorting the signal to the normal position and it is inserted and turned in lock A.
- This releases the points which may then be set for siding. Thus, while the setting of the points is for the siding, the main signal cannot be lowered.

Double lock and key system:

- In this system, a double lock is used. The working of this system is explained by taking a simple case, as shown in fig.



Double lock and key system

- If it is required to set the points for the siding, the signal for the main line is first resorted to the normal position.

- Then, K can be removed from the lock at B. This key is then taken and inserted in B compartment of double lock A and turned.
- This releases the working of points and when points are set for the siding, K can be removed from C compartment of double lock.
- The removal of K makes K stuck up in the B compartment of the double lock. K is now taken inserted and turned in the lock at C.
- This releases the working of trap points which can be brought to the close position.
- The key system can be used effectively in case of all signals, points, crossings and level-crossing gates near stations.
- The keys are kept in the station master's office and are interlocked with one another in such a manner that the keys relating to conflicting signals cannot be withdrawn at the same time.
- As shown in fig., let it be required to interlock the main line signal at B, the points at A and the trap points at C.
- The normal position of the main line signal is horizontal, the normal setting of the points is for the main line and the normal position of the trap points is the open position.
- For the normal setting, there will be three sets of locks provided, namely, one at B, a double lock at A and another lock at C.
- The two compartments of the double lock at A are just similar to B and C.
- Further, let K and K be the two keys for B and C respectively.

Route relay system:

- In this system, the points and signals for movement of trains are electrically operated.
- A panel with buttons is provided in the control cabin and it is possible to set the line merely by pushing the buttons in a very short time.
- It is the most modern and sophisticated system of interlocking. The adoption of this system results in considerable saving of man power and maintenance expenditure of cabins.

Construction of new lines:

- Depending upon the density of traffic, rolling stock, track, Signalling and various other facilities to be provided on the new line, the standard of the line is decided and accordingly its cost is worked out.

- The construction project of the new railway line is usually carried out in the following three stages:

Stage I:

- The minimum works required to carry materials are covered up under this stage.
- The main object is to save time and money on the transport of construction materials.
- The embankments and cuttings are not made of full width and the bridges are partially built or made of temporary nature.

Stage II

- The works required for carrying public goods traffic in addition to the construction material trains are covered up under this stage.
- The facilities required for opening a line for goods traffic are not elaborate and at the same time, it grants advantages in both ways financial as well as psychological.

Stage III:

- The line is practically completed in all respects and after getting the necessary approval from the concerned authority, it is opened for the passenger services.
- It may however be noted that if the project is a big one, it is split up into suitable sections and each section is completed in turn.
- When all such sections are completed, they are compiled together and the track is opened for traffic.

MAINTENANCE

The difference in the maintenance requirements of the railway track and the other civil engineering structures can be explained by the following two considerations:

Foundations:

- The foundations of most of the civil engineering structures like buildings, dams, bridges, etc. are solid and they do not get unduly strained with the loads coming on them.
- The railway track on the other hand rests on a floating foundation of ballast.

Nature of structure:

- The civil engineering structures are massive in nature and the live loads imposed on them are small.
- The structure of a railway track is delicate as compared to the heavy vehicles which run at high speed over it.

- The natural elements like rains, floods, winds, temperature variations, etc. will also exert their influence on the maintenance of a railway track.
- In this chapter, the various aspects associated with the maintenance of the railway track are explained briefly.

Necessity for maintenance of track:

There are mainly two reasons for maintaining the track in proper order:

New track:

- The newly laid railway track will settle down slowly and hence special gangs are to be employed to bring the embankment to the proper formation level.
- The number of men required will depend upon various factors. But generally 4 men are employed per kilometre length of the track for this purpose.

Constant use:

- The railway tracks are being constantly used by trains and hence they require some treatment to remain in the Working condition.
- This is achieved by providing maintenance gangs all along the railway track.
- The main function of these gangs is to keep the track in good condition.
- The railway track is divided into Suitable sections; each having a length of about 6 km for main line and 8 km for branch line section and one gang is attached to this section.
- The number of men required to maintain the railway track will depend on the volume of traffic, nature of soil and strength of the permanent way.
- In G.S.A. and Europe, the strength of maintenance gang is determined by allowing one man per 1.60 km length of track while in India, the provision is about I to 2 men per km length of track.

The topic of maintenance will be divided into the following three categories:

- Maintenance of track proper
- Maintenance of railway bridges
- Maintenance of rolling stock.

Maintenance of track proper:

- It consists of one gangmate or ganger, one keyrnan and nine to ten workers for B.G. and about four to five workers for MG.
- Each gang works in a length of about 90 metres a day.
- About ten to fifteen gangs are placed under a Sub-Permanent Way Inspector and one Permanent Way Inspector, commonly known as P.W.I., looks after two or three Sub-Permanent Way Inspectors.
- The duties of gangmate, keyman and P.W.l. are briefly discussed below.

Duties of a gangmate or a ganger:

Following are the duties of a gangmate:

- The ganger is the head of the gang and he is personally responsible for the upkeep of track in his section.
- The ganger must keep his section in good running condition at all times.
- The ganger is responsible for maintaining the track in his section in correct alignment and level.
- The ganger has to arrange for tools and other equipments required by his gang.
- The points and crossings should be periodically checked and examined by the ganger.
- In case of emergency, the ganger should stop or slow down a running train by the use of temporary signals.
- In case of an accident, the ganger should look after the broken fittings of the rolling stock and track components and see that these articles are not disturbed till they are seen and recorded by a responsible person.
- The ganger should be fully conversant with the details of his section such as number and location of points and crossings, level-crossings, etc.
- The ganger should prevent trespass of persons or cattle in the railway limits under his charge.
- He should also report of any unauthorized construction in his section.
- Sometimes the ganger is given miscellaneous duties such as noting high flood level of small bridges, cutting branches of trees obstructing vision of signals, repairing fencing, etc.

Maintenance of railway bridges:

The bridge inspectors who look after major bridges are responsible for the following works of maintenance:

- The soundings are to be taken in the river bed and depth of scour near the abutments and piers is to be detected.
- The suitable pitching is to be provided to the embankments near bridges.
- The flood training bunds will have to be constructed and maintained in case of some rivers.
- The superstructure of girder bridges should be painted with red lead at least once in 5 years.
- The rivets should be carefully inspected at regular intervals and all defective rivets should be punched off and replaced.
- The bearings of girders should be coated with oil from time to time.
- The bed blocks should be inspected from time to time and necessary repair should be immediately carried out.
- It should be seen whether the masonry has washed cracked or deteriorated.
- Any signs of movement of bricks or stones in masonry work should be carefully watched.
- It may be noted that most of the bridges are fairly old and they show signs of distress due to their age and fatigue.
- They therefore require special attention and care so as to ensure the safety of the rail traffic. It is necessary to take full advantage of the latest advancements in bridge technology while carrying out the bridge maintenance.

Maintenance of rolling stock:

The rolling stock includes locomotives, coaches and wagons. The rolling stock has to be maintained in perfect running order and the following special points need attention during the process of maintenance:

- The lubrication of all reciprocating parts and bearings should be carried out.
- The worn-out parts from the rolling stock should be replaced from time to time.
- It is very necessary to clean the different parts of the rolling stock everyday.
- All axles which have run 322 000 km should be replaced by new ones.
- The locomotive boilers have to be carefully maintained and they are renewed every 15 years.

- Just to create a spirit of competition and to inspire the performance of staff, contest should be held periodically to select the best black beauty of a particular zone of railways.
- The useful life of passenger vehicle is taken as about 30 years. Even if it is not worn out after this period is over, it is to be dismantled and re-assembled.
- The maintenance of rolling stock is carried out at about 50 main workshops located in 9 zones where locomotives, coaches and wagons have to go for complete overhaul on a strict periodic schedule.
- The day-to-day repairs are carried out in 300 locomotive sheds and 400 sick lines for coaches and wagons.
- The sizes of these workshops vary from big ones employing more than 15 000 workers to small ones engaging less than 150 workers.

MATERIALS

- The term materials management is used to indicate all the activities relating to the purchase, storage and utilization of materials required for running a business concern.
- It thus includes purchase planning, scheduling of requirements, determination of policy regarding holding of stocks of raw and finished materials, store keeping, issue of materials as required, etc
- Thus the main object of the materials management is to supply the user department with the required quantity at a constant rate as well as of uniform quality so that the production or service rendered by the user department is not unnecessarily held up.

Necessity in railways:

- The materials required include locomotives, passenger coaches, wagons, rails, sleepers, ballast, signal equipment, electric goods, coal, oil, spare parts of rolling stock, tools for maintenance, tickets, ledget. books, stationery articles and various other miscellaneous items.
- It is thus seen that the Indian railways are perhaps the only organizations which require such wide varieties of items ranging from a small pin to the sophisticated diesel locomotive.
- The Indian railways on an average have to purchase about one Iakh different items per year.

DRAINAGE

One of the essential requirement of a good railway track is an efficient drainage system.

Action of water: A railway track is subjected to the action of water in the following ways:

(I) by capillary action from the subsoil water;

(2) Seepage water from the adjoining area;

(3) Water from rainfall, dew and snowfall; and

(4) Water retained by pores of soil mass due to hydroscopic action

Importance of drainage: In case of railway track, the drainage is important because of the following facts:

(1) A slight increase in the moisture content reduces the bearing power of the subgrade and makes it unstable.

(2) If the drainage is not adequate, it may result in derailment of the track.

(3) The embankment gets eroded due to the action of surface and sub-surface water

(4)the track is subjected to heavy and fast loads, the excess moisture tends to deform the track and thereby the stability of the track gets reduced.

(5) There are chances of bank slips and land slides due to inefficient drainage.

Requirements of drainage system:

The railway track should provided with a good drainage system and for the purpose of convenience, it is broadly divided into the following two categories:

Surface drainage:

- The formation of track should be well above the level of the adjoining land so that the surface water does not flood the formation.
- The side drains should be provided to dispose off the surface water by cambering the formation and provision of necessary side slopes.
- The side drains should be of adequate size to carry the surface water.

Sub-surface drainage:

- The highest underground water level should be brought down sufficiently below the formation by suitable method.
- The water-logged areas should be given proper treatment
- As far as possible, the track alignment should be on pervious naturally drained soil.

Stabilization of track on poor soil:

- It becomes unavoidable to lay tracks on a very poor. soil having improper drainage facilities.

- In such cases, it becomes essential to improve the nature of the soil by some suitable method
- The various methods are found out to strengthen the subgrad4' of railway track under such circumstances.
- The choice of method will naturally depend on the climatic conditions of the country and the loads to be carried by the soil.

<u>Following are the five usual methods of stabilization of track on poor soil:</u>

(I) Layer or blanket of moorum or sand

(2) Cement grouting

(3) Sand piles

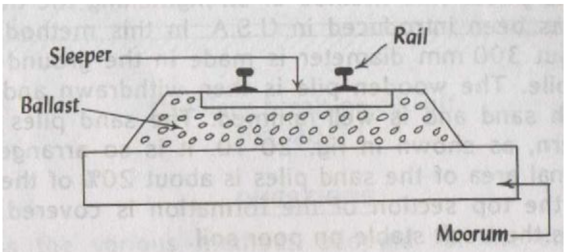
(4) Use of chemicals

(5) By providing capillary break or cut-off.

<u>Each of the above method of stabilization of track will now be briefly described.</u>

<u>Layer or blanket of moorum or sand</u>:

- In very poor soil such as black cotton soil which swells and shrinks considerably by contact with moisture and by the loss of moisture to the extent O 20% to 30% of its volume, a layer of moorum or sand is provided just under the ballast, as shown in fig.
- The thickness of this layer varies from 300 mm to 600 mm.
- This layer distributes the pressure and it also prevents the ballast from being lost is the cracks of the soil

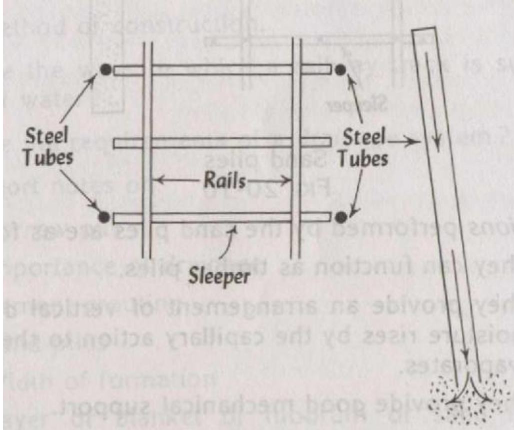


Layer of moorum

- Instead of moorum, other materials such as ashes, rubble, slabs of concrete, unserviceable sleepers, etc. are also used and they are found to be quite satisfactory.

<u>Cement grouting</u>:

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



Cement grouting

- The steel tubes are generally 1500 mm long and driven at an angle so that the end of the tube is nearly under the rail.
- Then the cement grout is forced under a pressure of about 0.70 N/mm through these tubes.
- The proportion of cement grout depends on the type and condition of the formation.
- The cement grout spreads through the poor soil and consolidates it. The steel tubes are then gradually taken out.
- This method is used to stabilize and strengthen the entire subgrade. The ratio of cement to sand may vary from 1: to 1:2 or even more

Sand piles:

- This method of strengthening the track laid for poor soil .
- In this method, a vertical bore of about 300 mm diameter is made in the ground by driving a wooden pile.
- The wooden pile is then withdrawn and the space is filled with sand and is well-rammed.
- The sand piles are driven in the pattern, as shown in fig.
- It is so arranged that the cross-sectional area of the sand piles is about 20% of the formation area.
- Thus the top section of the formation is covered with sand which makes the track stable on poor soil.

The functions performed by the sand piles are as follows:

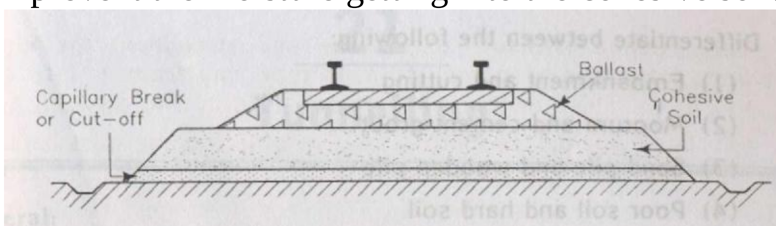
- They can function as timber piles.
- They provide an arrangement of vertical drainage. The moisture rises by the capillary action to the surface and evaporates.
- They provide good mechanical support.

Use of chemicals:

- In this method, the chemicals are used in place of cement grout to consolidate the soil.
- The silicate of soda followed by calcium chloride is effective for sandy soils containifl9 less than 25 per cent clay and silt.

By providing capillary break or cut-of:

- If the source of moisture in the soil below the formation is due to the capillary rise, the most effective way would be to provide a pervious layer of coarse sand.
- It will prevent the moisture getting into the cohesive soil.



Capillary break or cut-off

STATIONS AND YARDS

Definition of a station:

- A station is defined as any place on a railway line where traffic is booked and dealt with, and where an authority to proceed is given to the trains.

village

Features of a railway station:

The features of a railway station can be worked out from the requirements of the following:

(1) Public requirements
(2) Traffic requirements
(3) Requirements of locomotive department
(4) General requirements.

Public requirements:

The facilities to be given to the public at a railway station should be as follows:

(a) booking office,
(b) platforms,
(c) platform coverings
(d) arrangement of drinking water,
(e) suitable lights,
(f) sanitary arrangements,
(g) bathrooms,

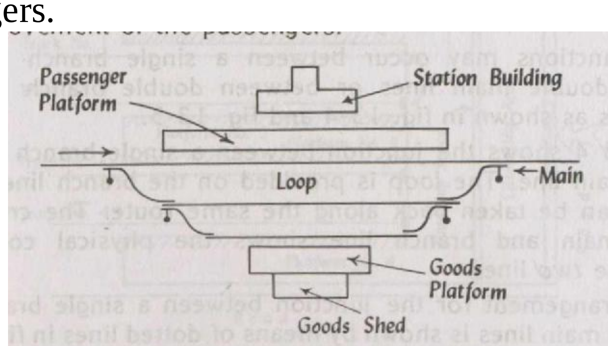
(h) waiting rooms and retiring rooms,
(i) refreshment rooms,
(j) public telephone,
(k)microphones to announce the arrival and departure of trains,
(l)guides to help illiterate passengers,
(m)refrigerators to supply cold water in hot weather,
(n)inquiry office attached with telephone,
(o)name-board of the station,
(p)police office to help the passengers,
(q)guide map of the city,
(r)boards showing reservation charts,
(s)charts showing ticket rates,
(t)big board showing arrivals and departures of the trains
at the station, etc.

Types of stations:

The stations can be divided into the following three types:
(1) Wayside stations
(2) Junctions
(3) Terminals.

Wayside stations;

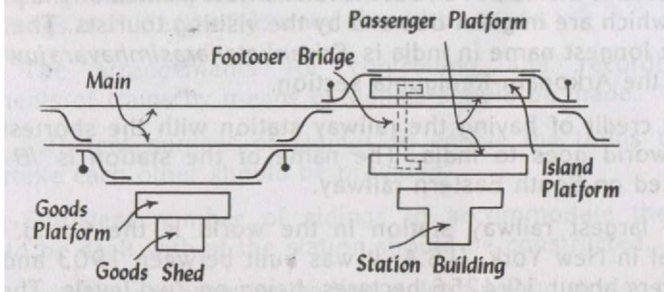
- In this type of stations, the arrangement is made to cross an up and a down train or for overtaking of the slower trains by the faster trains. Fig. and fig. show the typical layouts of wayside stations for single and double lines respectively.
- In fig., an island platform, completely surrounded by tracks, is formed.
- The over bridges or subways may be provided for the movement of the passengers.



Wayside station for single line

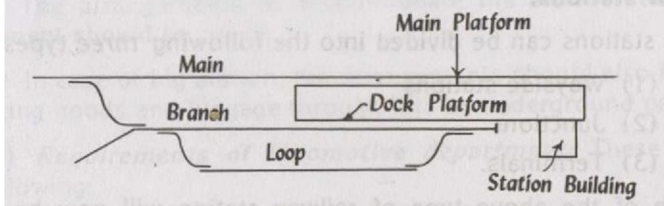
- Sometimes the branch lines are extended upto some portion of the main platform as shown in fig.
- This helps considerably in easy trans-shipment of passengers.

- This portion of the main platform on branch line is known as the dock platform.



Wayside station for double lines

FIG. 13-2



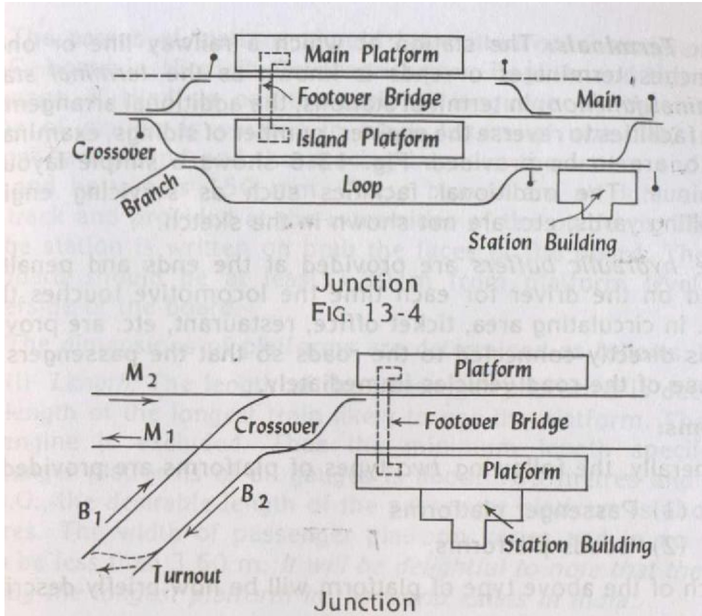
Dock platform

<u>Junctions</u>:

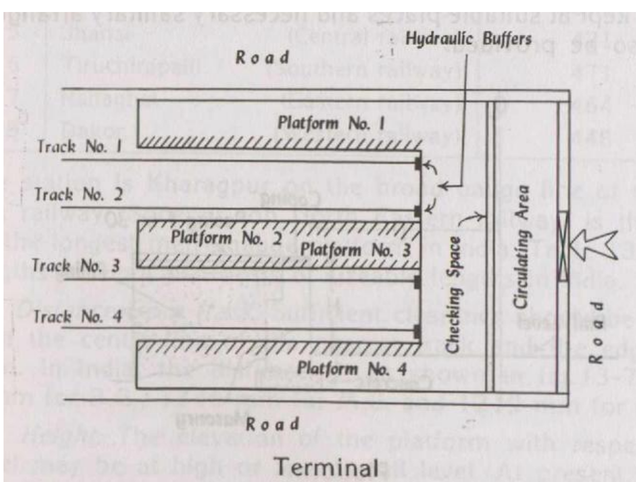
- In this type of stations, the branch line meets. the main line and hence the arrangements are made:

(a) to facilitate the interchange of traffic between main and branch lines, and
(b) to clean and repair the vehicles of the trains which terminate at the junctions.

- The junctions may occur between a single branch line and single or double main lines or between double branch line and main tracks as shown in fig.
- The arrangement for the junction between a single branch line and double main lines is shown by means of dotted lines in fig.
- A bridge is to be provided to facilitate the interchange of traffic between the main and branch lines.
- Figure shows the junction between a single branch line and main line.
- the loop is provided on the branch line so that can be taken back along the same route.
- The cross main and branch line shows the physical connection



- Fig shows the junction between double branch main lines.
- The cross-over between M and M enables of branch line B to proceed on branch line B on its return
- The arrangement for the junction between a single branch line and main tracks is shown by means of dotted lines in fig.
- A turnout is provided as shown and the remaining portion of branch line 2 is eliminated.
- lines and the train journey.



Terminals:

- The station at which a railway line or one oft its branches terminates or ends is known as the terminal station or terminal junction.
- In terminal stations, the additional arrangement such as facilities to reverse the engines, number of sidings, examination pits, etc. are to be provided. Fig. shows a simple layout of a terminus..
- The additional facilities such as servicing engines, marshalling yards, etc. are not shown in the sketch.
- The hydraulic buffers are provided at the ends and penalty is imposed on the driver for each time the locomotive touches these buffers. In circulating area, ticket office, restaurant, etc. are provided and it is directly connected to the roads so that the passengers can make use of the road vehicles immediately.

YARDS

Definition of a yard;

A yard is defined as a system of tracks laid within definite limits for various purposes such as storing of vehicles, making up trains, despatch of vehicles, etc. over which movements, not authorized by time table, may be made, subject to the prescribed rules, regulations and signals.

Types of yards:

For convenience, the classification of railway yards can be done in the following four categories:

(1) Passenger yards
(2) Goods yards
(3) Marshalling yards
(4) Locomotive yards.

Each of the above category of yard will now be briefly described.

Passenger yards:

- The main function of passenger yards is to provide facilities for the safe movements of the passengers and vehicles for the passengers.
- The passenger platforms, as discussed previously, may be considered as passenger yards.
- Similarly, at junctions or terminals, the separate sidings are provided to accommodate the passenger trains during their idle period.

Goods yards:

- These are provided for receiving, loading and unloading of goods.
- The goods platforms, discussed previously, may be treated as goods yards.
- Separate goods sidings will also have to be provided.

- It should be remembered that it is not possible to load the goods at all places where the train stops.
- Hence a made a conveyance unit and this peculiar characteristic traffic requires the provision of goods yards at a number along a railway line.
- or unload vehicle is of goods of places

Marshalling yards:

- The main purpose of having marshalling Yards is to isolate goods wagons received from various centres in the order of station at which they are to be sent.
- Thus in one way, they are working as distributing centres. Also the empty wagons are kept in marshalling yards and the same can be supplied as and when required by other stations.
- In fact, the function of a marshalling yard fl a railway system is like the function of heart in a human body.
- Considerable importance is therefore attached to the equipments and design of a marshalling yard.

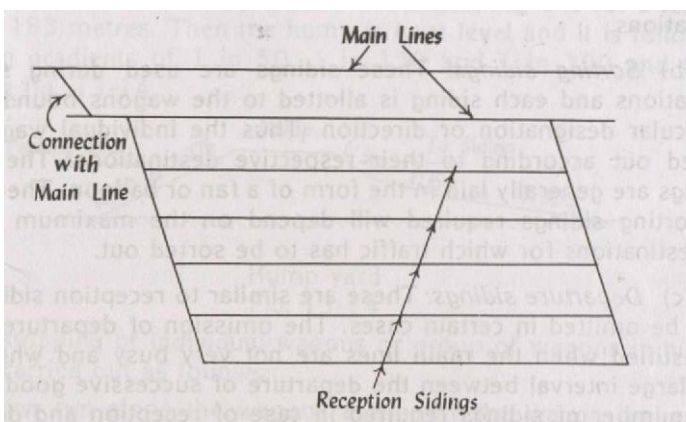
Features of marshalling yards:

An ideal layout of a marshalling yard consists of the following three types of sidings:

(a) Reception sidings

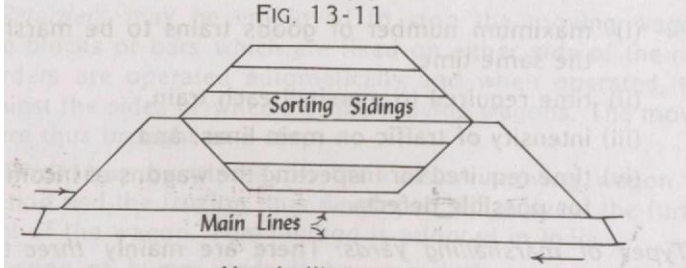
(b) Sorting sidings

(c) Departure sidings.

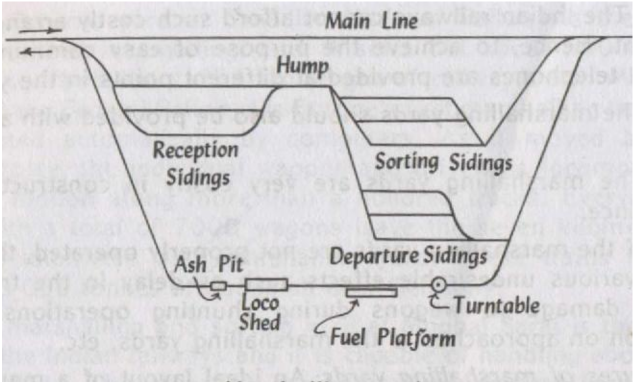


Marshalling yard

FIG. 13-11



Marshalling yard



Marshalling yard

Types of marshalling yards:

There are mainly three types of marshalling yards, namely, flat yards, gravitation yards and hump yards as discussed below:

Flat yards:

- In this type, all the sorting work is done by means locomotives.
- Hence this will require more consumption of power.
- But this type is the most suitable in cases where limited space is available for the layout of marshalling yards.

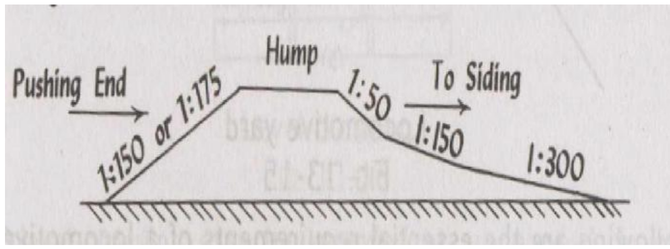
Gravitation yards:

- In this type, the tracks of the marshalling yards are laid at suitable gradient such that wagons move of their own accord and wagon brakes are kept to control the movements of these moving wagons.
- thus the shunting operations are carried out by gravity assisted by engine power.
- This is an ideal type of marshaIling yard. But the topography of the site may not permit such type of arrangement.

Hump yards:

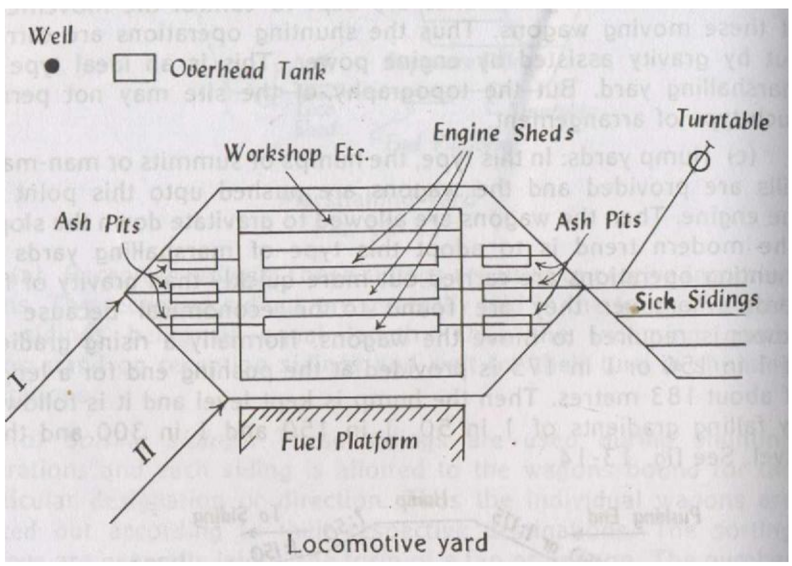
- In this type, the humps or summits or man-made hills are provided and the wagons are pushed upto this point by the engine.
- Then the wagons are allowed to gravitate down the slope.
- The modern trend is to adopt this type of marshalling yards as shunting operations are carried out more quickly than gravity or flat yards.
- Moreover they are found to be economical because no power is required to move the wagons.

- Normally a rising gradient of 1 in 150 or I in 175 is provided at the pushing end for a length of about 183 metres.
- Then the hump is kept level and it is followed by falling gradients of 1 in 50, 1 in 150 and I in 300 and then level.



Locomotive yards:

- These are provided for cleaning repairing, servicing, watering. oiling, etc. of the locomotives. Fig. shows a typical layout of a locomotive yard.



Following are the essential requirements of a locomotive yard:

- There should be a clear run from the traffic yard to the turn table.
- The turntable should not form an obstruction to any of the locomotives that are entering the yard.
- A second entrance should be available from the traffic yard which leads directly to the fuel platform. This also becomes useful when entrance no. I is blocked due to some reasons.
- The loop line for the fuel platform should be long enough to accommodate the longest train.

- The engine shed should be so laid out as to accommodate the maximum number of engines likely to come for repairs at the same time.
- The sick sidings should be easily accessible from the locomotive yards.
- The overhead tank and loco-well should be near the loco-shed as far as practicable.

UNIT-3
AIRPORT PLANNING AND DESIGN

Airport Planning

- Airport planning requires more intensive study an9 fore thought as compared to planning of other modes of transport.
- This is because aviation is the most dynamic industry and its forecast is quite complex.
- Unlike rail, road and water transportation, air transportation has yet not reached a steady state in design. it is very difficult to predict for the airport.

Airport Master Plan

- Airport master plan refers the planner's idealized concept of the form and structure of the ultimate development of the airport.
- This plan is not simply the physical from of ultimate development but a description of the st
- Master planning can apply to the construction of new airports as well as to significant expansion of existing facilities.

The objectives of the master plan according to FAA are:

- To provide an effective graphical presentation of the ultimate development of the airport are of the anticipated land uses adjacent to the airport.
- To establish a schedule of priorities and phasing for the various improvements proposed in the plan.
- To present the pertinent back-up information and data which were essential to the development of the master plan.
- To describe the various concepts and alternatives which were considered in the establishment of the proposed plan.

Planning of a new airport:

Step 1

- The most important item in a airport planning is to estimate the future volume of air traffic.
- Peak hoar volumes of passenger cargo and mail are required for proper allocation of space in the terminal building and for determining the size of the building. Peak hour aircraft movements assist in the design of runways, taxi and loading aprons.

Following data is collected for the traffic forecast

- Area to be served
- Origin and destination of the residents and non residents of the area
- Population growth in the area
- Economic character of the area
- Income level per capita
- Types of business activities and the labour employed
- Trends in existing local traffic
- Trends in national air traffic volume
- Population, growth and economic standards of adjacent areas

- Having collected the above data, the forecast of the traffic for some future years, say 15 years is carried out reviewing past trends of the local air traffic and future anticipated trends of the national air traffic.
- It may be pointed out that the process employed in making the forecast of air traffic is, however not a precise science.
- It requires considerable experience and judgment.

Step 2

The next step is to ascertain whether the existing airport can handle the amount anticipated air traffic.

Following points are considered in this respect

- Suitability of approaches for the type of airports.
- Capacity of runways and taxiways to handle the peak hour traffic (see chapter 7 for airport capacity
- Adequacy of terminal building of handling 4 passengers and cargo.
- Adequacy of aprons and servicing facilities.

Step 3

- If the foregoing considerations prove that the existing airport is inadequate to handle the anticipated traffic, the possible method for improving the capacity of the present airport should then be investigated.

The improvement can be done in the following ways

- Runway extensions, new or parallel runway' and high speed exit taxiways.
- Rearranging or increasing the size of terminal building and/or loading apron.
- Improving the traffic control devices

Step 4

- Inspite of all the possible ways as listed above, if it is worked out that the present airport cannot handle the air traffic, the designer thus arrives at the obvious answer, i.e to propose a new airport.

AIRPORT SITE SELECTION

- The selection of a suitable site for an airport depends upon the class of airport under consideration.

The factors listed below are for the selection of a suitable site for a major airport installation

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

Above factors are briefly discussed as follows

Regional Plan

- The site selected should fit well into the regional plan. there by forming it an integral part of the national network of airport.

Airport Use

- The selection of site depends upon the use of an airport i.e. whether for civilian or for military operations.
- Therefore, the airport site selected should he such that it provides natural protection to the area from air raids.
- This consideration is of prime importance for the airfields to be located in combat zones
- If the site provides thick bushes, the planes can be stored inside unnoticed. Sometimes the topography is such that the planes can be hidden by the underground installations.

Proximity to Other Airports

- The site should be selected at a considerable distance from the existing airports so that the aircraft landing in one airport does not interfere with the movement of aircraft at other airport.
- The required separation between the airports mainly depends upon the volume of air traffic, the type of aircraft and the air traffic control, i e. whether the airports are equipped with instrumental landing facilities or not.

The following minimum spacing have been suggested as a guide for planning

- For airports serving small general aviation aircrafts
- under VFR conditions 3 2 km (2 miles)
- For airports serving bigger aircrafts, say two piston engine, under VFR conditions 64 km (4 miles)
- For airports operating piston engine aircrafts under IFR conditions — 25.6 km (16 miles)
- For aircrafts operating jet engine aircrafts under IFR conditions — 160 km (100 miles)

Ground Accessibility

- The site should be so selected that it is readily accessible to the users.
- The airline passenger is more concerned with his door.to.door time rather than the actual time in air travel
- The time to reach the airport is, therefore, an important consideration specially for short-haul operations.
- The time required to reach an airport in a passenger car, from the business or - residential centre, should normally not exceed 30 minutes.
- The best location is a site adjacent to the main highway. This provides a quick access and minimizes the cost of an entrance road.
- Availability of public transportation facilities, e.g., bus, taxi dc, further qualifies the suitability of the site and may also improve the business potentiality at the airport.

Topography

- This includes natural features like ground contours, trees; streams etc.
- A raised ground e.g. a bill top, is usually considered to be an ideal site for an airport.

The reasons are:

- Less obstruction in approach zones and turning zones
- Natural drainage, low land may result in flooding
- More uniform wind
- Better visibility due to less fog

Obstructions

- When aircraft is landing or taking off, it loses or gains altitude very slowly as compared to the forward speed.
- For this reason, long clearance areas are provided on either side of runway known as approach areas over which the aircraft can safely gain or lose altitude.
- The areas should be kept free of obstructions.
- The obstructions may consist of fences, trees, pole lines, building and other natural or man made objects.
- Sometimes the ground itself may slope upwards from the end of the runways to such an extent that it forms an obstruction to the aircraft operation. If obstruction exists around a site over which an airport is to be built, the removal is imperative at any cost.

Visibility

- Poor visibility lowers the traffic capacity of the airport. The site selected should therefore be -free from visibility reducing conditions, such as fog, smoke and haze.
- Fog generally settles in the area where wind blow is minimum, e.g. in a valley, Smoke and haze nuisance exist at sites nearer to the industrial areas.
- Therefore, trend of the future development of industrial area should also be studied and the site should be selected accordingly.

Noise Nuisance

- The extent of noise nuisance depends upon the limb-out path of aircraft, type of engine propulsion nd the gross weight or aircraft.
- The problem becomes more acute with jet engine aircrafts.
- Therefore, the site shoulu be so selected that the landing and take off paths of the aircraft pass over the land which is free from residential or industrial development.
- Sometimes buffer zone may have to be provided between the tike off end of a runway and a nearby residential area.
- If buffer zone cannot be provided, some acoustical barrier may have to be installed.

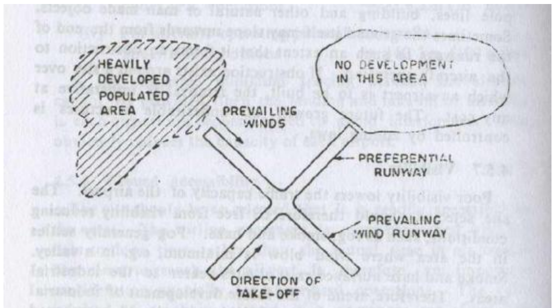


Figure 4.1 Area Recommended for Non-Residential Development

SURVEYS FOR SITE SELECTION

Traffic survey

To determine the amount of air traffic including the anticipated traffic for future.

Meteorological survey:

To determine direction, duration and intensity of wind, rainfall, fog, temperature and barometric pressure etc

Topographical survey

- To prepare contour map showing other natural features such as trees, streams etc.
- To prepare a map showing such constructed objects aspole lines, building, roads etc.

These maps will be helpful in the jobs of clearing, grading and drainage.

Soil survey

- To determine soil type and ground water table.
- This assists in the design of runway, taxiway, terminal building and the drainage system.

Drainage survey

- To determine the quantity of storm water for drainage. This can be obtained from the rainfall intensity and the contour maps
- To locate possible outlets for drain water in the vicinity of he site.
- To study the possibility of intercepting or diverting the natural streams of nallas flowing towards the site under consideration.

Material survey

- To ascertain the availability of suitable construction materials at a reasonable cost and the mode of transportation of these materials to the site.

ground contours and the cross-sections and longitudinal profiles

ZONING LAWS

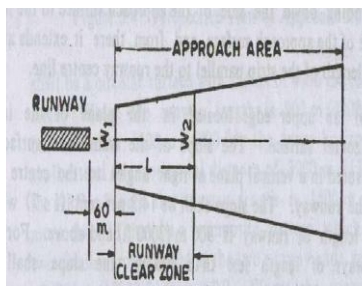
- The permissible height of structures depends upon the airport and the aircraft types which would use the airport.
- The use of land for manufacture of certain items which may result in smoke nuisance, foul odour etc. is also controlled by the zoning laws; It should, however, be con that all zoning ordinances are reasonable and the application is fair; otherwise they are likely to create resentment from t public and may result in mass disobedience.
- Whenever it is felt that the zoning laws are provocative, sufficient compensation should be announced in order to ascertain its effective implementation.

APPROACH ZONE

- During landing, the glide path of an aircraft varies from a steep to fiat slope. But during take-off, the rate of climb of aircraft is limited by its wing loading and engine power.
- As such wide clearance areas, known as approach zones are required on either side of runway along the direction of landing and take-off of aircraft.
- Over this area, the aircraft can safety gain or loose altitude.
- The whole of this area has to be kept free of obstructions and as such zoning laws are implemented in this area.
- The plan of approach zone is the same as that of the approach surface. , The only difference between the two is that while approach surface is an imaginary surface, the approach area indicates the actual ground area.

Clear Zone

- The inner most portion of approach zone which is the most critical portion from obstruction view-point is known as clear zone.
- Its configuration and dimensions are shown in Figure



	W_1	W_2	L
Instrument runway	300 m	525 m	750 m
Non-instrument runway			
(a) Large airport	150 m	270 m	600 m
(b) Small airport	75 m	135 m	300 m

RUNWAY DESIGN

- Runway is usually oriented in the direction of prevailing winds.
- The head wind. i.e. the direction of wind opposite to the direction of landing and take-off, provides greater lift on the wings of the aircraft when it is taking-off.
- As such the aircraft rises above the ground much earlier and in a shorter length of runway.
- During landing, the head wind provides a braking effect and the aircraft comes to a stop in a smaller length of runway Landing and take-off operate if done along the wind direction, would require longer runway.

Wind Rose

- The wind data, ie., direction, duration and intensity are graphically represented by a diagram called wind rose.
- The wind data should usually bi collected for a period of at least 5 years and preferably of to years, so as to obtain in average data with sufficient accuracy.

- As far as possible, these observations should be taken at or near 'site selected, since the wind conditions may vary considerably with location particularly in hilly regions.

<u>Wind rose diagrams can be plotted in two types as follows:</u>

Type I Showing direction and duration of wind

Type 11: Showing direction, duration and intensity of wind

<u>Type I Wind Rose</u>

- This type of wind rose is illustrated in Figure
- The radial lines indicate the wind direction and each circle represents the duration of wind.
- From the Table, it is observed that the total percentage of time in a year during which the wind blows from north direction is 10.3 percent. 'Ibis value is plotted along the north direction in

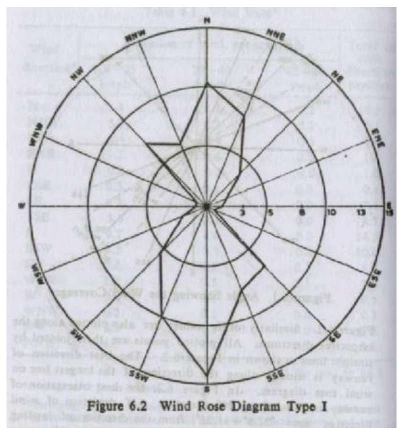
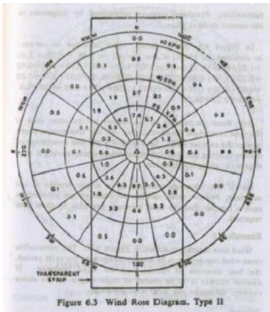


Figure 6.2 Wind Rose Diagram Type I

- Similarly other values are also plotted along the respective directions,
- All plotted points are then jointed by straight lines as shown in Figure
- The best direction of runway is usually along the direction of the longest line on wind rose diagram.
- In Figure the best orientation of runway is thus along NS direction.
- If deviation of wind direction up to (22.5'+ I 1.25') from the direction of landing and take-off is permissible, the percentage of time in a year during which the runway can safely be used for landing and take-off, will be obtained by summing the percentages of time along NNW. N. NNE, SSE. S and SSW directions.
- This comes to 57.0 per cent. Calm period, i.e., the percentage of time during which wind intensity is less than 6.4 kmph is also added to the above period.
- The total percentage of the time therefore comes to 57.0 + 13.5 705. This type of wind rose does nut account for the effect of cross wind component.

Type II Wind Rose

- This type wind data is used for of wind rose is illustrated in Figure
- The wind data as in the previous type. i.e. of Table 6.1 is used for this case.
- Each circle represents the wind intensity to some scale.
- The values entered in each segment represent the percentage of time in a year during which the wind, having particular intensity, blows from the respective direction.
- The procedure for determining the orientation of runway is described below
- Draw three equi-spaced parallel lines on a transparent paper strip in such a way that the distance between the two near by parallel lines is equal to the permissible cross wind component.
- This distance is measured with the same scale with which the wind rose diagram is drawn.
- In Figure, the permissible cross wind component is 25 kmph.
- Place the transparent paper strip over the wind rose diagram in such a way that the central line passes through the centre of the diagram.



- With the centre of wind rose, rotate the tracing paper and place it in such a position that the sum of all the values indicating the duration of wind, within the two outer parallel lines, is the maximum.
- The runway should be thus oriented along the direction indicated by the central line.
- The wind coverage can be calculated by summing up all the percentages shown in segment.
- The percentage value is assumed to be equally distributed over the entire area of the segment.
- When of the outer parallel lines of the transparent strip crosses a segment, a fractional part of the percentage appearing in that segment within the outside lines is also counted in the summation.
- Fractional areas are determined by judgment to the nearest decimal place.
- In Figure 6.3, the maximum wind coverage in per cent is obtained as (Calm period) + 7.40 + 5.70 + 2.40+1.20+0.80+0.30+4.30+5.50*9.70+6.30+3.60-.00+0.40-4-0.20+5.30+4.00 -f-2.70+2.l0+0.50+0.I0+0.03+2.lO+3.20

+4.60+3.20+ 0.30+ 0.25

- Read the bearing of the runway on the outer scale of wind rose where the central line on the transparent paper crosses the angular scale.

- In Figure the best orientation of runway is along the direction whose whole circle bearing is zero degree i.e. along NS direction.
- If the coverage provided by a single runway is not sufficient, two or more number of runways are planned in such a manner that the total coverage provided by them is as required.

Correction for Gradient

- Steeper gradient results in greater consumption of energy and as such longer length of runway is required to attain the desired ground speed. ICAO does not recommend any specific correction for the gradient.
- FAA recommends that the runway length after having been corrected for elevation and temperature should be further increased at the rate of 20% for every I per cent of effective gradient.
- Effective gradient is defined as the maximum difference in elevation between the highest and lowest points of runway divided by the total length of runway.

RUNWAY GEOMETRIC DESIGN

Runway Length

- The basic runway lengths as recommended by ICAOfor different types of airports are given in Table
- To obtain the actual length of runway, corrections for elevation, temperature and gradient are applied to the basic runway length

Runway Width

- ICAO recommends the pavement width varying from 45 m (150 ft to 18 m (60 ft) for different types of airports.
- The typical transverse distribution of traffic on a runway is shown in Figure
- The figure indicates that the aircraft traffic is more concentrated in the central 24 m (80 ft) width of the runway pavement.
- Another consideration in determining the runway width is that the outermost machine of large jet aircraft using the airport should not extend off the pavement to the shoulders.
- This is because the shoulder is usually of loose soil or established soil etc. which is likely to get into the engine and damage it;
- The outer engines of a large jet transport are about 13.5 m (45 feet) from the longitudinal axis of the aircraft.
- As such a pavement width of 45 m t provide adequate protection to the engine from the shoulder material during normal operations.

TERMINAL AREA

- It is the portion of an airport other than the landing area.
- It serves as a focal point for activities on the airport. It includes terminal and operational buildings, vehicle parking area aircraft service hangars etc.
- The terminal and operational buildings usually house all managerial and operational activities for the aircrafts.
- Vehicular circulation and parking also require careful study, if congestion and inconvenience to the airport users have to be avoided.

- The airport entrance or ac road from a highway must be located in such a way that it will avoid conflict with airport future development.
- Vehicle parking facilities should also be designed with a view to accommodate future expansion.
- The terminal apron is the loading and unloading area for passengers and cargo. Aircraft may also be fueled and parked here.
- At every airport provision of hangers for servicing and maintenance of aircrafts is planned.
- The size of these facilities is determined by the expected type and volume of airport activities.

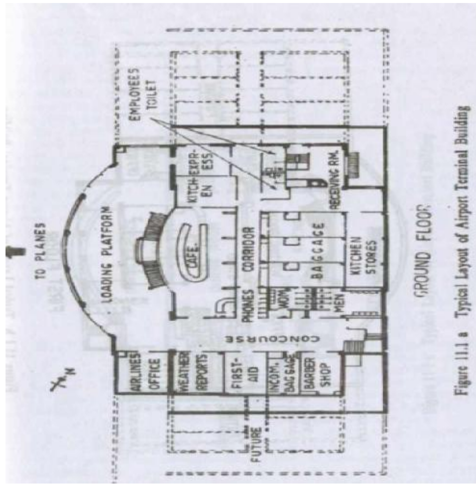
<u>BUILDING AND BUILDING AREA</u>

- The purpose of airport building is to provide shelter for various surface activities related to the air transportation.
- As such they are planned for the maximum efficiency, convenience and economy. The extent of the building area in relation to the landing area depends upon the present and future anticipated u of airport.
- Location of building area with respect to runway and taxiway should provide adequate space for future expansion of all structures.

<u>Building Functions</u>

<u>The various facilities provided in the airport buildings are as follows</u>

- Passengers bud baggage handling counters for booking
- Baggage claim section
- Enquiry counter
- Space for handling and processing mail, express and light cargo
- Public telephone booth
- Waiting hall for passengers and visitors
- Toilet facilities
- Restaurants and bars
- First aid room
- General store and gift shops
- Space for magazines, news display etc.
- Office space for airport staff
- Weather bureau
- Post office and banking facilities
- Custom control
- Passport and health controls
- Control tower



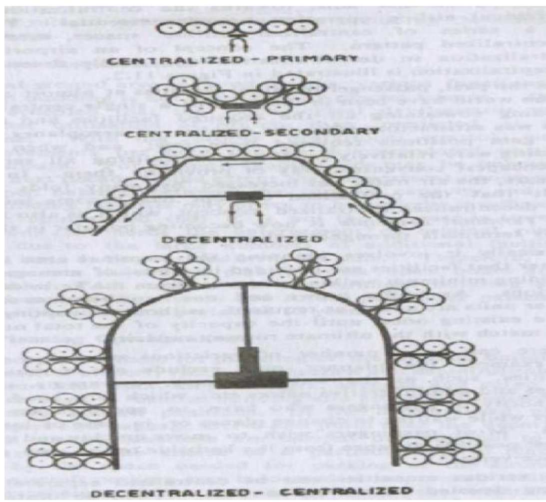
<u>Site Location</u>

- The correct placement of the terminal building with respect. to the runways and loading aprons result in a more rational approach for the airport development.
- As the planning of runway proceeds, the requirements of building sites are also kept constantly in view.
- The location of the runways are finalized with proper designation of adequate building area.
- The suitability of an area, as a site for terminal building development, is evolved in accordance with the following requirements
  - Sufficient area for the first stage of building development with possibility of future expansion
  - Sufficient area for roadways
  - Adequate area for car parking
  - Layout of above items providing functional relationship with each other
  - Convenient access of the main highway
  - Central location with respect to runway
  - Proximity and easy installation of utilities, e.g.telephone electricity, water, sewage, etc.
  - papers, advertisement

<u>Planning Considerations</u>

- Two concepts are there for planning of the terminal buildings for a commercial airport, viz., centralization and decentralization.
- In the centralized plan, all passengers, baggage and cargo are funneled through a central building and are then dispersed to the respective aircraft positions.
- In the decentralised plan, the passengers and baggage arrive at a point near the departing plane.
- All airline functions are carried out adjacent to the departing plane.
- The choice of a particular type of plan is governed by the space needed for parking of the aircrafts.
- When the aircraft parking area is located at an overall walking distance exceeding 180 m. a change from the centralized system becomes necessary.

- Further, when the number of gate positions (loading area required for each aircraft) required for the individual airliner at one airport exceeds the decentralized plan also becomes operationally uneconomical.
- At this situation, another shift towards the ceatralization of each individual airline Operation becomes essential.
- This results in a series of centralized airline spaces, arranged in a decentralized pattern.
- The concept of an airport from the centralization to decentralization and finally decentralization to centralization is illustrated in Figure
- In the past, passenger terminal facilities at almost all airport in the world have been in the form of a single central terminal building containing all the required facilities and amenities.



- This was satisfactor3i when the number of aeroplanes used and the gate positions required were few; and when terminal building were relatively small and centralizing all services are the cheapest convenient way of providing them.
- In the last 20 years, the air traffic has increased by many folds with the result that the centralized concept has become inoperative.
- The decentralized-centralized concept which is also known as Unit Terminal Principle is now becoming popular in the design of air terminals.
- There can be a number of variations of such a concept.
- For example the planner may exclude all or most of the amenities, such as the waiting rooms, restaurants, shopping arcades and administrative offices etc., which are used only by a minority of passengers who have to spend some time at airport while waiting to change planes or in case of long flight delays.
- Most passengers wish to move quickly and over the shortest possible distance from the kerb side to the gate position and vice-versa.
- The various amenities can be centralized separately in a building, devoted exclusively to them.
- It may be located close and connected with the operating units and may serve a single Unit, or a group of them.
- The operating or handling units Would be purely functional with only such essential amenities as book stall, money changer, flight insurance booths and toilets.

- This concept of a separate building for amenities would lend itself conveniently to the separation of domestic and international.
- The principle of a separate structure connected with the handling Units should be applied wherever possible, leaving space for additional units to meet later expansion needs.
- The unit terminal principle fits in exceptionally well with the modern concept of parallel runway patterns at large airports.
- Finally, the unit terminal concept automatically minimizes initial capital expenditure, while ensuring that addition can easily be made later, without rendering any of the previous expenditure as waste.
- The International Airport Committee, has recommended that full consideration be given to the adoption of the unit terminal principle for the new terminal facilities to be constructed at the international airports in India.

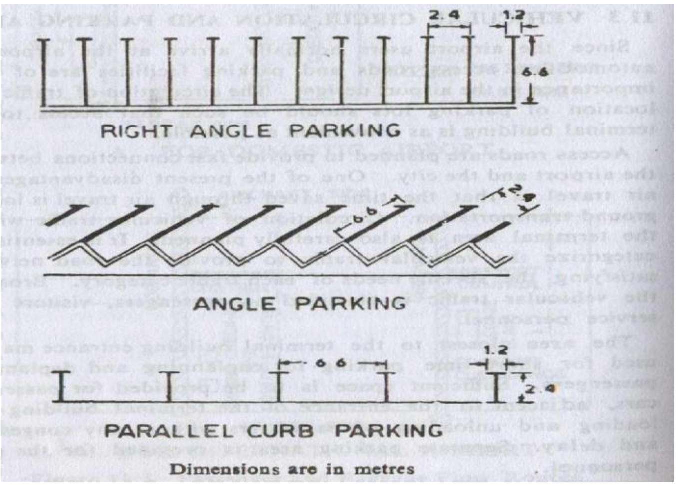
Vehicular Circulation and Parking Area

- Since the airport users normally active at the airport in automobiles, access roads and parking facilities are of vital importance in the airport design
- The circulation of traffic and location of parking lots should be such that access to the terminal building is as convenient as possible.
- Access roads are planned to provide fast connections between the airport and the city.
- One of the present disadvantages of air travel is that the time saved the air travel is lost in ground transportation.
- Circulation of vehicular traffic within the terminal area is also carefully planned. 1i is essential to categorize she vehicular traffic to provide the road network satisfying the specific needs of each traffic category.
- Broadly, the vehicular traffic is classified as passengers, visitors and service personnel.
- The area closest to the terminal building entrance may be used for short time parking for enplanning and deplanning passengers.
- Sufficient space is to be provided for passenger cars, adjacent to the entrance of the terminal building for loading and unloading of passengers without any congestion and delay.
- Separate parking area is provided for the staff personnel for the most efficient airport vehicular circulation and parking system,

The following points are considered

- Ease of passenger unloading and loading at the terminal building
- One way traffic wherever possible.
- A minimum of driveway intersection.
- Adequate driveway width to permit overtaking.
- Sufficiently and clearly defined parking and circulation routes
- Well lighted routes for pedestrians and vehicles.
    - For determining the size and type of parking facility necessary, a traffic survey should be conducted. IAA suggests that the size of the public parking facility should be based on 1.5 to 2 cars for each peak hour passenger.

- The pattern of parking is dictated by the shape and size of the parking area available.
- The basic parking patterns usually adopted are shown in Figure 11.4.



<u>Nose-in and angled nose-in</u>

The advantages of this configuration are:

- Less noise while taxing in because no turning is required.
- Hot blast is not directed towards the terminal building.
- The aircraft forward door is close to the terminal building.

The disadvantages are:

- The aircraft rear loading door is far away from terminal building

<u>Nose-in and angled nose-out</u>

The advantages of this configuration are as follows:

- Less power is required while maneuvering the aircraft out of its gate position.
- The rear loading door is close to the terminal building.
- Overall apron area required is generally small.

The main disadvantage is:

- The hot blast is directed towards the terminal building.

<u>Parallel System</u>

The main advantage of this system is:

- Both, the front and the rear doors are adjacent to the terminal building.
- But this type of. parking configuration requires more space.
- Further, the noise and the hot blast are directed towards the adjacent gale position.
- Thus, it is evident that no single parking configuration can be considered as an ideal one.

<u>Aircrafts can be grouped adjacent to terminal building in various ways</u>

- Frontal system
- Open apron .system
- Finger system
- Satellite system

These parking systems are illustrated in Figure and are discussed below

Frontal system

- It is very simple and economical 5 But its use is limited only to small airports requiring few gate positions.

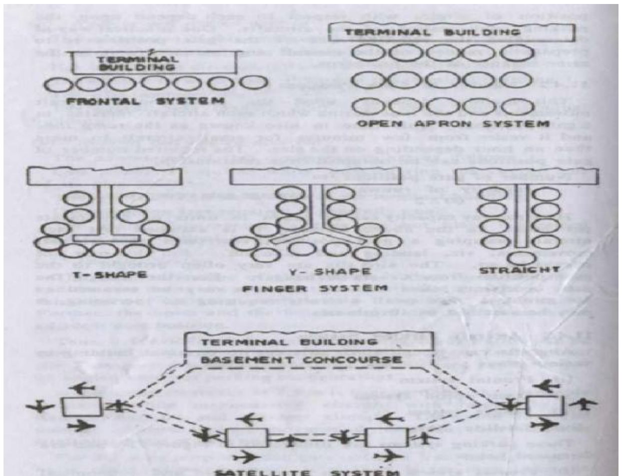


Figure 11.6 Aircraft Parking System

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 or reach the aircrafts parked in the outermost row.
- They are thus exposed to weather, noise and hot blast of the jet aircrafts.
- To protect the passengers front 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 passengers, for entering and leaving the aircraft, often require extensions of the terminal building.
- Such extension is known as pier finger.
- A typical arrangement is shown in Figure
- The pier finger can be fenced open walkway or a closed structure, single or multistoried.
- It can be a straight, 1-shaped or Y-shaped.

Its main advantages are

- If enclosed, it provides adequate protection to the passengers from weather, noise, fumes etc. even when they come out of the terminal building.
- Future expansion is easier.
- All aircrafts remain close to the terminal building.
- It permits the installation of a short nose loading bridge or a swinging gang plank for the convenience of the passengers.

Satellite system

- ❖ Satellites are small buildings located on the apron.
- ❖ Aircrafts are parked around the satellite buildings which are connected to the main terminal building by underground tunnel.
- ❖ This system is in use at the International airport of Los Angeles.
- ❖ It is advantageous, compared to the pier finger system only when the connections to satellite buildings are through the tunnels.
- ❖ In such an arrangement, the aircrafts are parked near the satellite as shown in Figure
- ❖ Less turning is required to maneuver the aircraft in and out of the gate position.

The disadvantages of this system are

- ➢ Large construct cost.
- ➢ Passengers have to change the levels several times as they leave the terminal building for boarding the aircraft.

TYPICAL AIRPORT LAYOUTS

The typical airport layouts for the basic runway configuration are illustrated in figure

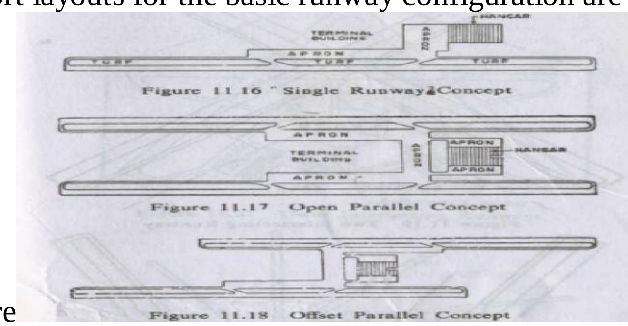


Figure 11.16 Single Runway Concept
Figure 11.17 Open Parallel Concept
Figure 11.18 Offset Parallel Concept

- ➢ The first step in the airfield design is the selection of suitable runway configuration.
- ➢ There should be a good correlation between the runway and other airport elements, viz. taxiway terminal building, apron, hangar etc.
- ➢ The integration of all the elements of an airport provides a smooth flow of traffic, keeps the taxi distances to a minimum and provides the shortest route for passengers.
- ➢ A proper airport layout provides full functional efficiency with the minimum 5 utilization.
- ➢ An engineer should attempt to provide the simplest design which yields the optimum service to air passengers.

A good airfield layout should possess the following Characteristics

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

UNIT-4

AIRPORT LAYOUTS, VISUAL AIDS, AND AIR TRAFFIC CONTROL

VISUAL AIDS:

- The pilot needs visual aids while landing or taking off during all weathers and at every time.
- The pilot usually takes help of the perspective view of the runway and other ground reference marks during the landing operations.
- Runway threshold, runway edges and the runway centre line are amongst the most essential items which should be clearly visible to the pilot.
- In order to enhance the day time visibility, runways, taxiways and other allied structures are marked with lines and numbers.
- All the markings should be clear and should provide the maximum practicable contrast under all conditions.
- In the day time during poor weather conditions, or at night, the visibility reduces considerably.
- It is essential to provide adequate lighting in the airport which should convey the similar information's to the pilot during visibility conditions, as the markings do in day time.

RUNWAY LIGHTING

- After crossing the threshold, the pilot completes a touchdown and then rolls the aircraft on the runway. The runway lighting is so planned 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.
- The old practice for night landing was to floodlight the entire landing area. But these days, flood-lighting is restricted only to indicate the preferred direction of landing.
- For runway lighting, a more precise design commonly known as narrow-gauge pattern is almost universally used at major airports.
- The lighting pattern is illustrated in Figure. As the pilot crosses the threshold and is about to touch the runway, he finds the central area of the runway excessively dark.
- To eliminate this black hole effect, the practice was to increase the intensity of the edge lights, but this proved to be ineffective.

- The narrow-gauge pattern is an attempt towards lighting up the central portion of the runway. In this system, as shown in Figure.
- Groups of high intensity lights are placed IS m apart and on either side of the centre line of runway. They continue up to a distance of 1140 m from the

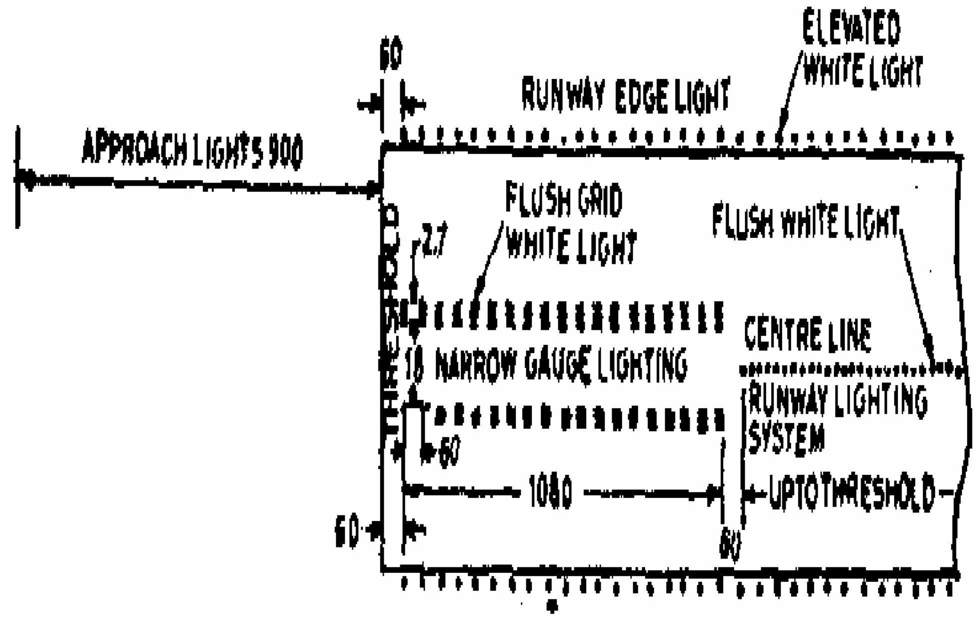


Figure 1.Narrow-Gauge Pattern for Runway's lighting

Beyond this distance closely spaced lights are placed along the centre line which extends up to the other end of the runway. All the lights on the runway edges are elevated type and those inside the runway are of the fletch type.

TAXIWAY LIGHTING

The following design considerations apply to taxiway lighting

(i) Taxiway should be clearly identified so that they cannot be confused with the runways.
(ii) Exit taxiway should be so lighted that the pilot is able to locate the exit 360 to 450 m (1200 ft to 1500 ft) ahead of the point of turn off.
(iii) There should be adequate guidance along the taxiway.
(iv) Crossing of taxiway and the runway should be clearly identified.

(v) Effective and simple presentation of guidance elements to permit rapid aircraft movement between runway and apron should be preferred.

- ❖ The taxiway lighting layout is illustrated in Figure2. On tangent portion, the lights are placed not more than 60 m apart, at a distance of 3 m from either edge along the taxiway.
- ❖ The spacing is reduced on curves and intersection to facilitate their clear identification. Spacing of light on curves is given in Table 12.1. All taxiway side lights are colored blue and usually project not more than 0.32 m (13 in) above the pavement surface.
- ❖ On exit taxiway, in order to clearly identify the point of turn off, lights are placed along the centre line of the exit taxiway.
- ❖ With this arrangement, the taxiway .centre line, at its junction with the runway centre line, forms a distinct V-shaped pattern. The centre line light is green in colour and placed at 6 to 7.5 m (20 to 25 ft} distance along the straight length and 3 to 3.6 m (10 to 12 It) distance along the curves.

APRON

Is a paved area for parking of aircrafts, loading and unloading of passengers and cargo. It is usually located close to the terminal building or hangars. The size of apron depends upon

(I) Size of loading area required for each type of aircraft.

This area is also known as gate position.

(ii)Number of gate positions.

(iii) Aircraft parking system.

SIZE OF GATE POSITION

This depends upon the following factors

(i) The size of the aircraft and its minimum turning radius.
(ii) The manner in which the aircraft enters and leaves the gate position under its own power or when pushed by a tractor.
(iii) Aircraft parking configuration Aircraft are parked causing the least interference due to heat, fumes and blast during maneuvering into and out of the gate position Jet engines are more critical in this respect than the piston engine aircrafts. The basic parking configurations are illustrated in Figure. The merit and demerits of each art discussed below

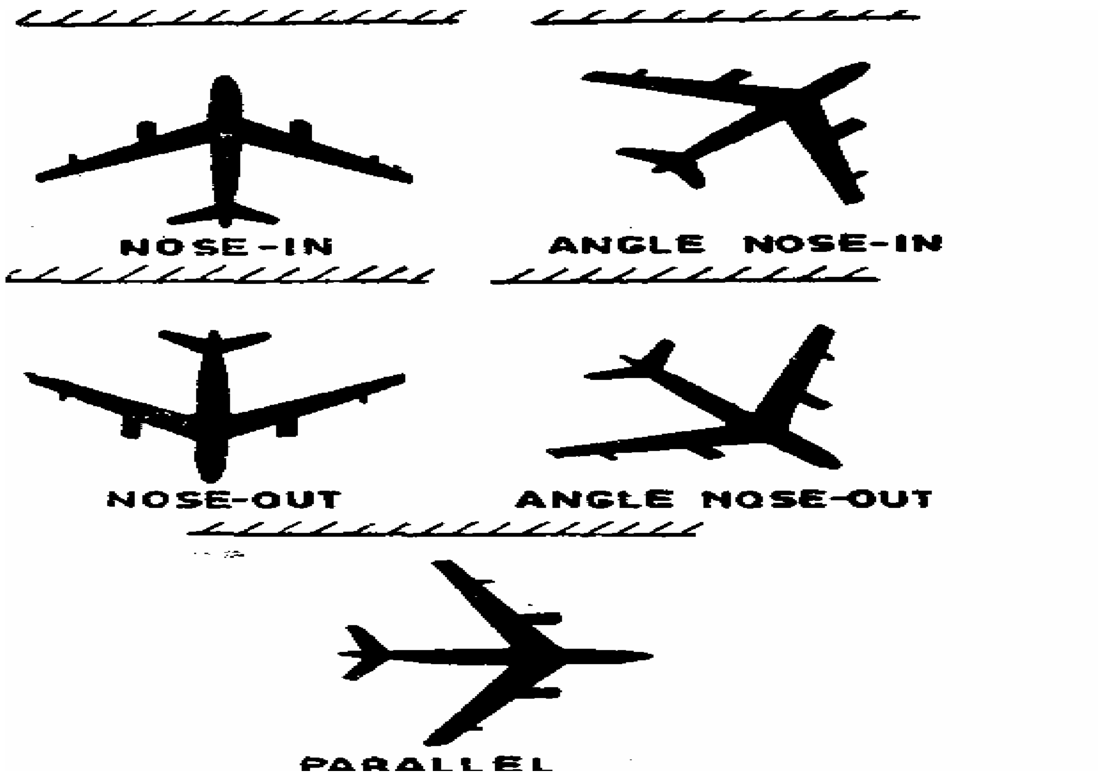


Figure Basic Parking Configurations of Aircrafts

(a) NOSE-IN AND ANGLED NOSE-IN:

The advantages of this configuration are

- Less noise while taxing in because no turning is required.
- Hot blast is not directed towards the terminal building.
- The aircraft forward door is close to the terminal building.

The disadvantages are

- The aircraft rear loading door is far away from terminal

The advantages of this configuration are as follows

- The rear loading door is close to the terminal building.
- Overall apron area required is generally small
- Building

(b)NOSE-IN AND ANGLED NOSE-OUT:

The advantages of this configuration are as follows

- ❖ Less power is required while maneuvering the aircraft out of its gate position.
- ❖ The main disadvantage is that the hot blast is directed towards the terminal building.

(c) PARALLEL SYSTEM:

- ❖ The main advantage of this system is that, both, the front and the rear doors are adjacent to the terminal building. But this type of parking configuration requires more space.
- ❖ Further the noise and the hot blast are directed towards the adjacent gate position.
- ❖ Thus, it is evident that no single parking configuration can be considered as an ideal one.
- ❖ A study made by International Air Transport Association concludes that airlines prefer to use an angled nose-out parking configuration.
- ❖ A minimum clearance of 7.5 m is suggested as the desirable clearance while maneuvering aircraft with respect to the terminal building and adjacent aircraft.
- ❖ The guide lines and number of personnel on the ground to guide the pilot also control the size of gate position.
- ❖ For planning purposes each gate position can be represented by a circle whose diameter is slightly larger than twice the minimum turning radius of the aircraft.
- ❖ But it is however not necessary to keep circles separated by the suggested minimum clearance of 7.5 in.
- ❖ They can even overlap. The position of circles with respect to each depend upon the parking configuration of the aircrafts

NUMBER OF GATE POSITION:

- ❖ This mainly depends upon the peak hourly aircraft movements and the time during which each aircraft remains in a gate position.
- ❖ This time in also known as the ramp time and it varies from few minutes for small aircraft to more than an hour depending on the size.
- ❖ The required number of gate positions can be obtained from relationship,
- ❖ It is assumed that each aircraft occupying a gate position represents two aircraft movements, viz, landing and take off. But this may not always be so.
- ❖ The aircrafts are very often brought to the gate position from a service hangar.

- For the design, the gate occupancy time for big aircrafts may be assumed as 60 minutes. For small aircrafts requiring no servicing, it may be assumed as 10 minutes.

TERMINAL AREA:

- It is the portion of an airport other than the landing area.
- It serves as a focal point for activities on the airport, it includes terminal and operational buildings, vehicle parking area, aircraft service hangars etc.
- The terminal and operational buildings usually house all managerial and operational activities for the aircrafts,
- Vehicular circulation and parking also require careful study, if congestion and inconvenience to the airport users have to be avoided.
- The airport entrance or access road from a highway must be located in such a way that it will avoid conflict with airport future development.
- Vehicle parking facilities should also be designed with a view to accommodate future expansion.
- The terminal apron is the loading and unloading area for passengers and cargo. Aircraft may also be fueled and parked here. At every airport, provision of hangers for servicing and maintenance of aircrafts is planned.
- The size of these facilities is determined by the expected type and volume of airport activities.

BUILDING AND BUILDING AREA:

- The purpose of airport building is to provide shelter and space for various surface activities related to the air transportation.
- As such they are planned for the maximum efficiency, convenience and economy.
- The extent of the building area in relation to the landing area depends upon the present and future anticipated use of airport.
- Location of building area with respect to runway and taxiway should provide adequate space for future expansion of all structures.
- Building setback distances from runways and taxiways as discussed in article are provided for safe clearance during maneuvering of aircrafts under the varying conditions of instrumental and visual operations.

BUILDING FUNCTIONS:

- The essential building categories for a commercial airport are terminal and operational. The size of each category may vary depending upon the scope and type of operations.
- Terminal building usually refers to a building mainly, used for passengers, airline and administration facilities.
- Its layout is such as to offer the enplaning passengers, the convenient and direct access from the vehicle platform or street side of the building, through the booking and waiting rooms, to the aircraft loading positions on the apron.
- Deplaning passengers are also provided with a direct route from the aircraft to the baggage claim counter and then to the vehicle platform.
- The operational category includes control tower, weather bureau and other government services related to the aviation.
- In many cases the terminal building fulfills the function of the operational building as well.

The various facilities provided in the airport buildings are as follows

(i) Passengers and baggage handling counters for booking
(ii) Baggage claim section
(iii) Enquiry counters
(iv) Space for handling and processing mail, express and light cargo
(v) Public telephone booth
(vi) Waiting ball for passengers and visitors
(vii) Toilet facilities
(viii) Restaurants and bars
(ix) First aid room
(x) General store and gift shops
(xi) Space for magazines, news papers, advertisement display etc.
(xii) Office space for airport staff
(xiii) Weather bureau
(xiv) Post office and banking facilities
(xv) Custom
(xvi) Passport and health controls
(xvii) Control tower

AIR TRAFFIC CONTROL

- ❖ The need of air traffic control is mainly for two reasons. Firstly, to safeguard life and property and secondly to expedite the traffic movements.
- ❖ Later in turn results in an orderly flow with no congestion and delay. The problem of controlling the pound vehicular traffic is much simpler than that of the aircrafts in space.
- ❖ If a motor vehicle looses its control, it can be parked on the road without much interfering the flow of traffic stream. Further the control techniques are unchanged with weather conditions.
- ❖ Two basic characteristics of aircraft make the air traffic control a complex problem. Firstly, an aircraft must continue its flight and cannot afford to stop in the air space.
- ❖ The helicopter is an exception to this which can hover in the air at a constant location as long as engine power is available.

The second characteristic is that the aircraft lands with a gliding slope dictated by the altitude at which the trouble occurs. During bad whether conditions, when visibility is poor, certain information regarding alignment height and distance from the runway threshold are to be provided to the pilot through some instruments.

The passengers today are favoring the air travel. The aircrafts speed and air traffic density re also growing faster. Landing and take-off operations may reach fifty millions yearly or even more in the near future. As far as aircrafts and airports are concerned, they can be designed and built to any number. Their economic and effective utilization, therefore, depends upon the air traffic control system. This system can handle large aircraft movements both safely and expeditiously. Conflicts in air traffic control signals can seriously reduce the capacity of a given airport. ICAO has certain flight rules which are necessary to be followed by all member nation for flights on international routes. Flight service stations are located along the air routes to provide contacts to the pilot during the course of his flight from one apron to another. It is essential that at all times the pilot during their flights have contacts with one of the controlling stations of two airports or with the flight service station along the air route.

NEED OP AIR TRAFFIC CONTROL

The control of air traffic deals with that phase of air transportation which ensures safe, convenient and economic movement of aircraft from one airport to another airport. The aircraft flight from one airport to another involves the following basic actions.

1. The aircraft takes off from an airport.
2. It maintains a proper altitude in air.
3. It navigates from point to point safely.

4. It lands at the desired airport.

The system of air traffic control mainly concerns with the above items. The primary functions of air traffic control devices can therefore be summarized as follows:

(I) **Air traffic control:**

This deals with the following:
(a) To guide the aircraft, desiring to land or takeoff.
(b) To control the taxing of arriving and departing aircraft on the airfield between the apron and the runway.

(Ii) **A traffic control:**

This regulates the movement of aircraft along the air routes with adequate lateral and vertical separation to avoid collision. This is particularly essential when visibility is poor.

(Ill) **Airway communication :**

This deals with conveying of airway and weather information to the pilot during the flight.

(iv) **General or non-airway traffic control :**

This presents a serious problem when persona! 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 follows
I Control within terminal area
2 Control over airways
3 Airway communications

The method of traffic control for each system depends upon the weather conditions. These are commonly known as visual fiightrules (VFR) and instrumental flight rules (IFR). If VFR conditions prevail, the air traffic control during the route is practically not required, since the pilots can maintain the desired separation by visual aids. The IFR conditions exist, when the visibility is lower than the limits prescribed for flight under visual flight rules. Rigid traffic control has to be exercised under IFR condition. The pilot, prior to his departure, prepares a flight plan which indicates the aircraft destination, the air route to be followed, the desired altitude and the estimated time for departure. If the flight plan is approved, no change is allowed without prior approval of the traffic control centre.

HANGER:

- ❖ The primary function of a hanger is to provide an enclosure for servicing, overhauling and doing repairs of the aircrafts.
- ❖ They are usually constructed of steel frames and covered with galvanized iron sheets.
- ❖ They are also provided with machine shops and stores for spare parts
- ❖ The size of hangers depends upon the size of aircraft and its turning radius; adequate lighting inside the hanger is of prime importance.
- ❖ Sometime ceilings of hanger and some portions of its side walls are glazed, which work as light reflectors.
- ❖ Construction of single hangar to store large number of aircraft. May be undesirable both from economy and other considerations viz., difficulty in the maneuvering of aircrafts, noise nuisance, fumes, fire hazards etc.
- ❖ The number of hangars depends upon the peak hour volume of aircrafts and demand of hangars on rental basis by different airline agencies.

Hangar site Location:

If hangar can be located close to the terminal building and loading aprons, such an arrangement offers many advantages. But is should be ascertained that this arrangement offers adequate scope for future expansion of the terminal as well as the hangar facilities; otherwise the functional efficiency of the entire airport would be impaired. The requirements of suitable hangar site are as follows

(i) The site should be such that there is a convenient road access to it from the site to the aprons and terminal buildings.

(ii) Proximity to and easy installation of utilities, e.g., electricity, telephone, water supply and sewers etc.

(iii) Reasonable proximity to the loading apron.

(iv)The site should not be along the direction of frequent storms as this is likely to damage the hangar doors etc.

(v) Sufficient area to provide car parking facilities for working personnel.

(vi) Favorable topograph providing good natural drainage.

(vii) Adequate site area for future expansion of hangar facilities.

UNIT-5
HARBOUR ENGINEERING AND OTHER MODES OF TRANSPORT

Water transportation:

The water transportation can further be subdivided into two categories:

- inland transportation and
- Ocean transportation.

Inland Water transportation

- Inland Water transportation is either in the form of river transportation or canal transportation.
- Ocean Water transportation is adopted for trade and commerce.
- It is estimated that about 75 per cent of international trade is carried out by shipping.
- The development of navy force is intended for national defence.
- Ocean water transportation has n limitation and it possesses high flexibility.

Definitions

Harbours:

- 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

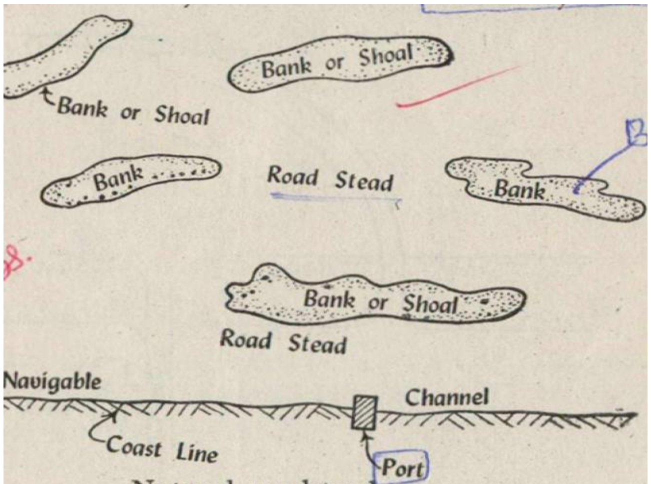
Semi-natural harbours:

- 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.

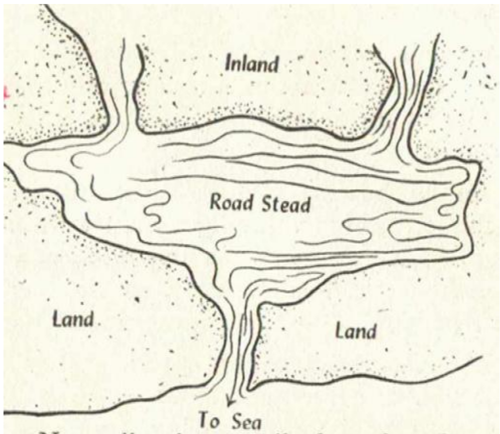
❖ Thus, a naval vessel could obtain shelter during bad weather within a tract or area of water close to the shore, providing a good hold for anchoring, protected by natural or artificial harbour walls against the fury of storms



Natural roadstead

Natural roadsteads:

➢ A deep navigable channel with a protective natural bank or shoal to seaward is a good example of a natural roadstead as shown in fig..

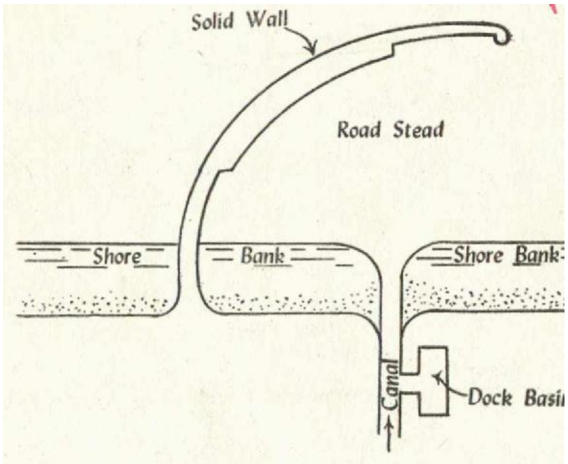


Naturally circumscribed roadstead

➢ A confined area naturally enclosed by islands as in a creek if available is known as a circumscribed natural roadstead.

Artificial roadsteads:

➢ These may be created suitably by constructing a breakwater or wall parallel to the coast or curvilinear from the coast



Artificial roadstead

- As an alternative a circumscribed artificial roadstead could be formed by enclosing tract provided good anchorage, by projecting solid walls called jetties, from the shore.
- Another method is to create a confined basin of small area having a narrow entrance and exit for ships.
- Such roadsteads with smaller inner enclosures and wharf and with loading and unloading facilities are commonly provided for fishing vessels.

From their utility and situation, harbours are further classified into three major types:

- Harbours of refuge including naval bases
- Commercial harbours, connected with ports
- Fishery harbours.

It is necessary to study the requirements of these types of harbours and provide for such requirements.

Requirements of harbour of refuge:

- Ready accessibility
- Safe and commodious anchorage
- Facilities for obtaining supplies and repairs

Requirements of commercial harbour:

- Spacious accommodation for the mercantile marine.
- Ample quay space and facilities for transporting; loading and unloading cargo.
- Storage sheds for cargo.
- Good and quick repair facilities to avoid delay.
- More sheltered conditions as loading and unloading could be done with advantage in calmer waters.

Accessibility and size of harbours

- Accessibility depends on the location of the harbours.
- The harbour entrance should be designed and located for quick easy negotiation by ships, overtaken by storms.
- At the same time, it should be narrow enough not to expose the harbour to the effects of the stormy sea.
- Maximum dimensions upto 180 have been adopted
- The entrance is generally placed of the sea, with a passage to the interior of the harbour so arranged as to minimize the effect of rough seas.

Thus; the size is determined by:

- ❖ Accommodation required.
- ❖ Convenience for maneuvering and navigation.
- ❖ Adaptability to natural features.

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 planning:

The important facts to be studied and scrutinized can be enumerated as follows:

- ➢ It is necessary to carry out a thorough survey of the neighbourhood including the foreshore and the depths of water in the vicinity
- ➢ The borings on land should also be made so as to know the probable subsurface conditions on land. It will be helpful in locating the harbour works correctly
- ➢ The nature of the harbour, whether sheltered or not, should be studied.
- ➢ The existence of sea insect undermine the foundations should be noted.
- ➢ The problem of silting or erosion of coastline should be carefully studied.
- ➢ The natural metrological phenomenoa should be studied at site especially with respect to frequency of storms, rainfall, range of tides, maximum and, minimum temperature and of winds, humidity, direction and velocity of currents, etc.

Ports:

- The term port is used to indicate a harbour where terminal facilities, such a stores, landing of passengers and cargo, etc. are added to it.
- Thus, a harbour consists of the waterways and channels as far as the pier head lines and a port includes everything on the landward side of those lines i.e. piers, slips, wharves, sheds, tracks, handling equipment, etc.

Classification of ports:

Depending upon the location, the ports can be classified as;

- Canal ports
- River ports and
- Sea ports
  - The term free port is used to indicate an isolated, enclosed and policed area for handling of cargo; etc. for the purpose of reshipping without the intervention of customs.
  - It is furnished with the facilities for loading and unloading; for storing goods and reshipping them by land or water; and for supplying fuel.
  - Free port thus indicates an area within which goods can be landed, stored, mixed, blended, repacked, manufactured and reshipped without payment of duties and without the intervention of custom department.
  - Depending upon the commodities dealt with or their use, the ports can also be classified as grain ports, coaling ports, transhipment ports, ports of call, etc.
  - Depending upon the size and location, the ports can also be grouped as major ports, intermediate ports and minor ports
  - A major port is able to attract trade and it commands a really pivoted position for the extension of communications.

Port design:

The design of a port should be made while keeping in mind the following requirements:

- The entrance channel should be such that the ships can come in and go out easily.
- The ships should be able to turn in the basin itself.
- The alignment of quays should be such that the ships can come along side easily even when there is an on-shore wind.
- The width behind the quay should be sufficient to deal with the goods.
- There should be enough provision for railway tracks to take care for loading and unloading of cargo.

Requirements of a good port

- It should be centrally situated for the hinterland. For a port, the hinterland is that part of the country behind it which can be served with economy and efficiency by the port.
- It should get good tonnage i .e. charge per tonne of cargo handled by it.
- It should have good communication with the rest of country.
- It should be populous
- It should be advance in culture, trade and industry.
- It should be a place of defence and for resisting the sea-borne invasion
- It should command valuable and extensive trade.
- It should be capable of easy, smooth and economic development.
- It should afford shelter to all ships and at all seasons of the years

- It should provide the maximum facilities to all the visiting ships including the servicing of ships.

TIDES AND WAVES:

Some of the natural and meteorological phenomena which primarily affect the location and design of the harbour.

They are as follows:

- Coastal currents and evidences of sitting, including littoral drift or coast erosion.
- Tides and tidal range.
- Wind, wave and their combined effect on harbour structures.

Tides:

- Tides on the coast-line are caused by the sun and moon.
- The effect of tides is to artificially raise and lower the mean sea level during certain stated periods.
- This apparent variation of mean sea level is known as the tidal range.

Spring tides and Neap tides:

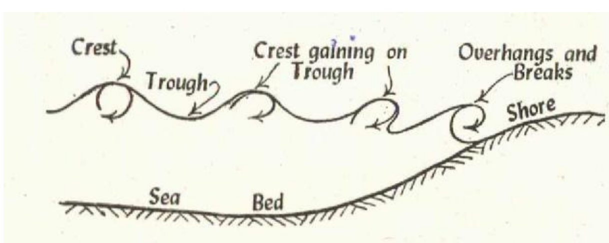
- At new and full moon or rather a day or two after (or twice in each lunar month), the tides rise higher and fall lower than at other times and these are called Spring tides.
- Also one or two days after the moon is in her quarter i.e. about seven days from new and full moons (twice in a lunar month), the tides rise and fall less than at other times and are then called neap tides.

Waves and wind:

- The ‘sea wave’ is by far the most powerful force acting on harbour barriers and against which the engineer has to contend.
- The wave has the impulse of a huge battering ram and equipped with the point of a pick axe and chisel edge”.
- It is the most in compressible natural phenomena.
- The formation of storm waves takes place in the open sea due to the action of wind.

Water waves are of two kinds:

- Waves of oscillation and
- Waves of translation;
  - The former are stationary, while the latter possess forward motion.
  - But all translatory waves originally start as waves of oscillation and, become translatory by further wind action.
  - The harbour engineer’s main concern is the translatory wave.



Wave movement

Breakwaters:

- The protective barrier constructed to enclose harbours and to keep the harbour waters undisturbed by the effect of heavy and strong seas are called breakwaters.

Alignment:

- A good alignment for a breakwater is to have straight converging arms so that the angle of inter section does not exceed 60 degrees.
- It is desirable to avoid straight parallel or diverging arms running out to sea.

Design of breakwaters:

Following information should he collected before the design of a breakwater:

- Character of coastal currents
- Cost and availability of materials of construction
- Directions and force of prevailing winds
- Nature of the bottom or foundation
- Probable maximum height, force and intensity of waves. !

The three important rules to be observed in the design of a breakwater are as under:

- The design should be based on the extreme phenomena of the wind and waves, and not on the mean or the average.
- The height of the wave should he determined by Using the equation H = 034¥Fand the height of wall should be decided accordingly by making sufficient allowance for freeboard.
- It should be seen that the material in the foundation is not subject to scour.

Detrimental forces acting on breakwaters:

Hydrostatic force:

- This force reduces the apparent weight and hence, the marine structures suffer these losses to a great extent unless the foundations are absolutely impervious.

External forces:

- The intensity of external forces, especially wind and wave action, is enormous.
- The power of wind produces vibrations in the masonry structure and weakens the different courses of masonry.
- In a similar way, the wave when it recedes induces ‘suction action and it results in the erosion of the foundation unless it is made safe and secure.

Solvent action of sea water:

- This quality of sea water causes damage to the materials of construction

Sea insects:

- The concentrated action of sea insects results in the undermining of the hardest and the soundest building material and it is for this reason that the marine structures are made specially bulky and strong.

Classification of breakwaters:

Breakwaters are classified mainly into three types:

- Heap or mound breakwater
- Mound with superstructure
- Upright wall breakwater.

Heap or mound breakwater

- It is a heterogeneous assemblage of natural rubble, undressed stone blocks, rip rap, supplemented in many cases by artificial blocks of huge bulk and weight, the whole being deposited without any regard to bond or bedding.

- This is the simplest type and is constructed by tipping or dumping of rubble stones into the sea till the heap or mound emerges out of the water, the mound being consolidated and its side slopes regulated by the action of the waves.
- The quantity of rubble depends upon the depth, rise of tides and waves and exposure.
- On exposed sites, the waves gradually drag down the mound, giving it a flat slope on the sea face.
- As far as possible, such flattening has to he protected.
- The disturbing action of the waves is the most between the high and low water levels.
- Consequently, all protective methods are adopted above the low water level.
- Protection is also very necessary to the top of the mound and outer or exposed face.

WHARVES

- Platforms or landing places are necessary for ships to come, close enough to the shore, for purposes of embarkation, disembarkation, etc. at the same time.
- These platform locations should give sufficient depth of water for the ship to float.
- Such platforms are, called wharves.
- They are built out into or on to. the water
- Thus, a wharf affords a working platform alongside the ship in continuity of the shore.
- A wharf is quay but the term wharf is generally used for an open structure of piles or posts with bracings, jutting from the shore towards the sea.
- A wharf may be a sheet pile wall or it may consist of a piled projection with or without artificial retention of soil some distance behind or it may be a gravity wall.
- Wharves may either be parallel to the shore and abutting against it or they may project into the water either at right angles or oblique to the shore.
- The former type is adopted at places where depth of water is sufficient for the ships to berth, say 10 m to 12 m
- The latter type is adopted at places where depth of water near the shore is not enough for the ships to enter safely.
- The level of wharf should be above the high water level. But at the same time, it should be economical to load the vessels when the water level is low.
- Wharf should act as a unit when there is an impact from any vessel.
- Hence, it should be properly braced and bolted. It is desirable to provide rounded corners for wharves which art likely to be used by large vessels.
- Such a construction will result in a smooth entry of vessels into the slips

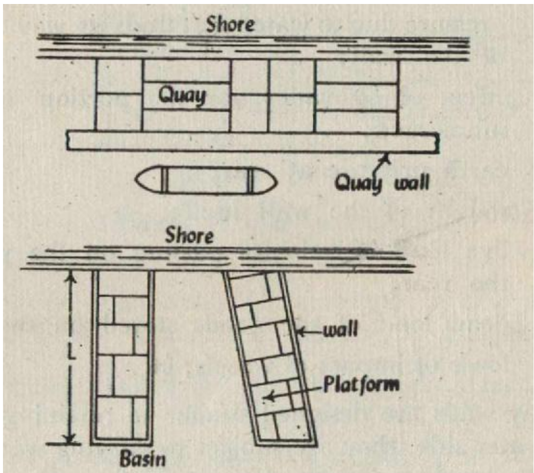
PIERS

- The structures which are built perpendicular or oblique to the shore of a river or sea are known as piers.
- In the sea the piers are constructed where the sea is not deep and the natural harbour is not convenient for allowing the ships to berth adjacent to the shore.
- In many cases, the piers are constructed with piles, columns and braces leaving good space for the ocean current to flow without causing any obstruction.

- The dimensions of a pier should be worked out very carefully.
- Its length should be sufficient to accommodate the longest ship likely to take its advantage.
- In other words, it should project beyond the bow or stern of the ship so as to protect its hull. Its width should be sufficient to satisfy its utility.
- It can be stated that the pier should be of sufficient width to allow easy unloading of cargo without any undue delay.

QUAYS

- Wharves along and parallel to the' shore, are generally called quays and their protection walls are called quay walls



Quay walls

Design of quay walls:

They are built to retain and protect the embankment or filling:

- Factors affecting the design are as follows
- Character of foundation;
- Pressure due to water that finds its way to the real of the wall;
- Effect of buoyancy for the portion of the wall submerged;
- Earth pressure at rear;
- Weight of the wall itself;
- live load of vehicles passing on the platform at the rear;
- dead load of the goods stored on the platform;
- force of impact of vessels; etc.
    - Quay wails are designed similar to retaining walls;
    - But on the water side, they are subject to varying water pressure (owing to level variations due to tides), and on the land side, earth and contained water pressures, with proper allowances for surcharge.

JETTIES:

- These are the structures in the form of piled projections and they are built out from the shore to deep water and they may be constructed either for a navigable river or in the sea.

- In rivers, the jetties divert the current away from the river bank and thus, the scouring action is prevented.
- As the current is diverted to deep waters, the navigation is also controlled.
- In the sea, the jetties are pr at places where harbour entrance is affected by littoral drift or the sea is shallow for a long distance.
- Thus, they extend from the shore to the deep sea to receive the ships.
- In a limiting sense, a jetty is defined as a narrow structure projecting from the shore into water with berths on one or both sides and sometimes at the end also.
- Jetties are exposed to severe wave action and their structural design is similar to that of breakwater.
- However, the designed standards may be released to a certain extent due to the fact that the jetties are usually built normal to the most dangerous wave front.
- The impact caused by the berthing ships will depend on the skill of the berthing officer, local condition of currents, wind, etc.
- The berthing velocity depends upon the condition of approach, wind, etc. and it decreases with the increase in the size of the ships

FENDER:

- The cushion which is provided on the face of jetty for ships to come in contact is known as fender.
- It is provided for various forms and is made of different materials.
- The common material used as fender for jetties is the framework of timber pile driven into the sea bed at a short distance from the jetty and filling the space with coiled rope, springs, rubber, buffers, etc.
- The fender system controls the relative motion between dock and ship caused by wind and waves.
- Hence, it also prevents the paint of ships being damaged.

For the purpose of classification, the fenders can be classified in the following four categories:

Rubbing strips:

- In its simplest form, the fender system adopted for small vessels consists of rubbing strips of timber, coir padding or used rubber tyres
- It is also convenient to use pneumatic inflated tyres, either by suspending them or installing them at right angles to jetty face.
- The inflated big-size tyres are useful to transfer cargo between mother ship and daughter ships.
- The pneumatic rubber fenders are very useful for transferring cargo from ship to ship of big sizes.

Timber grill:

- This system consists merely of vertical and horizontal timber members fixed to the face piles.
- This is a simple form of fender and to make it more effective, energy fender piles may be driven along the jetty face with cushion or spring inserted between them.

Gravity-type fendering system:

- As the ships grew in size, this s came into force and in its simplest form, it consists of a weighty fender which is raised up when there is an impact of the berthing ship and thus, the initial energy of shock, is absorbed.

Rubber tendering:

- Due to the development of rubber technology and with, further growth in ship size, rubber fendering is preferred at present.
- The shapes of rubber fenders may be cylindrical, square, V-shape or cell type.

NAVIGATIONAL AIDS

Necessity for signals:

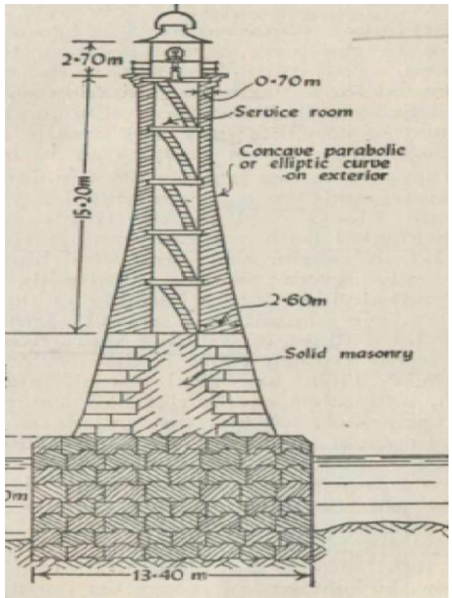
The mariner and his ship have to be guided by proper signals during navigation, especially,
(1) to avoid dangerous zones like hidden rocky outcrop and sand bars,
(2) to follow proper approaches and
(3) to locate ports.

Fixed and floating light stations:

- The light stations when they are built on land are called fixed as in the case of permanent lighthouse structures.
- Such structures are located either in the hinterland close to the shore or in the sea on submerged outcrops and exposed to the fury of the waves.
- Alternately, where there are difficulties in establishing proper foundations; floating light rations in the form of a light vessel may be adopted.
- Buoys of standard shapes also belong to the ‘floating type and are generally used to demarcate boundaries of approach channels in harbour basins.

Lighthouse:

- It is a lofty structure popularly built of masonry or reinforced concrete in the shape of a tall tower on a high pedestal.
- The tower is divided into convenient number of floors, the topmost floor containing powerful lighting equipment and its operating machinery.
- The lower floors are used, as stores and living rooms necessary for the maintenance and working of the light station.
- The main parts of a typical lighthouse tower are illustrated in fig.
- Lighthouses may be located on shore or on islands away from the mainland as in the case of warning light stations.

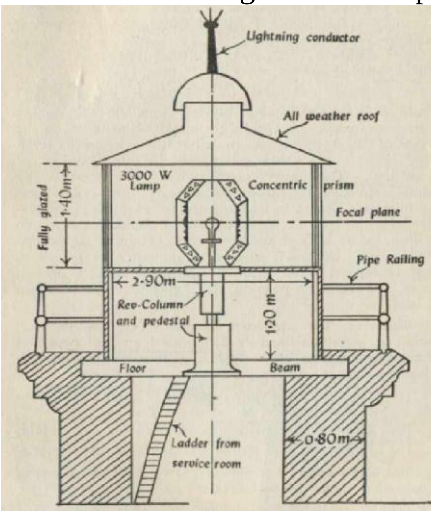


- In the former case, the lighthouse may be easily connected with the nearest village or township by proper communications, while in the later situation it is located far habited area.
- In either case as a matter of convenience and urgency, all the requirements for the efficient and unfailing maintenance and working of the lighthouse, like stores and staff quarters are provided in the lighthouse shaft.

Lighthouse construction:

- It is quite evident that the type of foundation to be adopted for a particular situation will depend on the characteristics of soil of that area.
- On good rock or hard soil, a thick bed of concrete may serve while on submarine or marshy locations, piles or caissons could be used.
- The superstructure is generally a masonry or an R.C.C tower constructed on a prominent basement.
- The stone or concrete blocks used in the construction of the basement are joggled both vertically and horizontally as shown in fig.
- To secure and bind the blocks together and resist strongly forces tending to dislodge or move them.
- The tower is divided into a number of floors and the light is housed at the summit in a glazed room.
- The floors are accessible by a flight of winding stairs from bottom to top.
- Just below the lantern room is the service room and other rooms lower down are used for oil and general stores, personnel, and other accessories like water storage and fire fighting apparatus.
- A narrow gallery is provided outside the lantern room protected by pipe railing.
- The dimensions and geometrical shapes shown in the figure are adopted in modern practice and more recent lighthouse like the Eddystone are examples of this type of construction.
- The light should be identified and its distance ascertained, for the mariner to locate his position.

- These lights are made ‘fixed’ or flashing for easy identification by the navigator and are classified accordingly to their illuminating power.
- The height of the tower above sea level determines the geographical range and the intensity or power of the light the luminous range.
- These two are important factors, deciding the range of visibility.
- The illumination is both refracted through powerful lenses and prisms and reflected or flashed by highly polished hyperbolic concave mirrors fig.shows the details of the light apparatus.
- Fixed lights are likely to be confused with the private lights of the neighbourhood and hence, it is desirable to avoid fixed lights as far as possible.



Signals:

- The approach channel of a modern port should be clearly defined o demarcated by the provision of suitable signals.

Thus, signals will be required at the following places:

- Light ships have to be provided at important changes in the direction of the route of ships.
- Lighted beacons are to be fixed on river banks
- Buoys are required at entrance channels to ports

Requirements of a signal

- It should be conspicuously visible, from a long distance.
- It should not vary in character and should be positively recognizable.
- It should be simple for identification.

Types of signals:

The signals are broadly divided into the following three categories’:

1. Light signals
2. Fog signals
3. Audible signals.

The first classification of light signals is very important. Fog signals and audible signals are occasionally used.

Light signals

These signals are subdivided into three types:

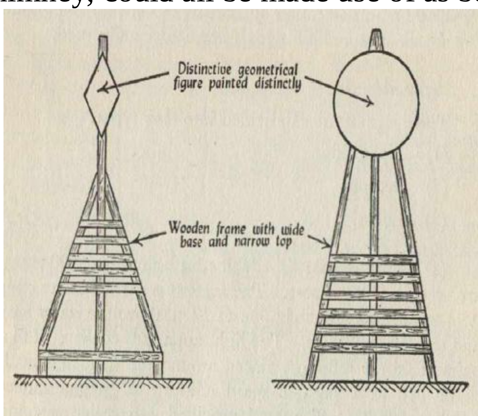
(1) Light ships
(2) Beacons
(3) Buoys.

Light ships:

- Small ships displacing about 500 tonnes are used for this purpose.
- The lantern is carried on an open steel tower approximately 9 m to 12 m above the water level and erected amidships.
- The light apparatus consists of four pairs of mirror reflectors placed around the light and made to revolve at a suitable speed emitting ,a predetermined number of flashes.
- The ship is with service personnel and is securely anchored or moored.
- light ships are more stable and the lights in them more steady which is an important factor for a mariner.
- The hulls of light ships are built of steel and they are generally painted with red colour.
- The name of the station is painted in white colours on both sides of light ship.
- The superstructures are also provided with white colours.
- The storm warning signals are also installed on the light ships.
- When the light ships are being overhauled, red colour relief light ships with the word 'Relief' on the sides are used.

Beacons:

- Any prominent object, natural or artificially constructed, easily indentifiable and capable of being used as a means to indicate and guide in navigation is generally designated as a beacon.
- Lofty topographical feature like hill summit, building or structure like a church steeple, or factory chimney, could all be made use of as beacons.

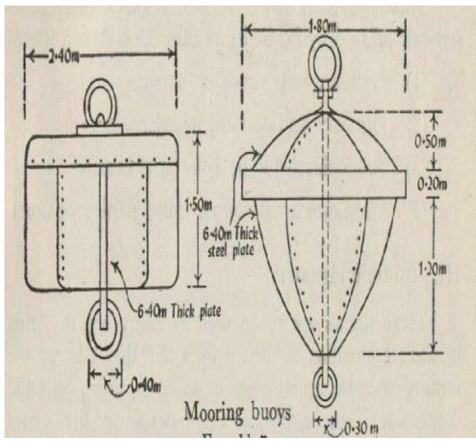


Beacons

- Alternately, a beacon could be built in the form of an open tapering frame work, with a wide stable base and gradually narrowed top, terminating in a distinctive figure, like a triangle or circle as shown in fig.
- The distinctive geometrical figure is suitably painted so as to cause prominence.

Buoys:

- Buoys are floating structures of small size employed for demarcation like entrances, approach channel used for indicating direction changes in means of alignment. Beacons are thus of the navigation.
- Beacons are navigation or as immense help in boundaries and so on.
- They are moored to sinkers, or heavy anchors, with the help of heavy chains, whose length are two to three times the depth of water and which are 70 to 90 mm in diameter.
- They are useful in indicating approach channel widths, two rows of buoys being used one along each boundary.
- These buoys are denominated 'Star board-hand' or 'port-hand' buoys according to their positions being to the left or right of the navigator respectively as he approaches the harbour.
- Buoys are of different designs and patterns. They are designed not only to support their own weight, but also the weight of cables or chains by which they are moored.
- The surface of buoy structure near water line should be protected by the provision of stout wooden fendering so that it is not seriously damaged in case of an impact.
- Thus, buoys are floating signals and they are usually prepared of steel and iron plates of minimum thickness 6 nun.



- Buoys are hollow structures and they are constructed in two watertight sections so that in case one of them is leaky, at least the other one may prevent it from sinking.
- The maxi mum distance between consecutive buoys is about 16Q0 m in estuaries and in narrow channels, it is about 150 m to 300 m.
- The diameter of a buoy varies from 1 80 m to 3 m.
- In tidal places, the depth of water is liable to fluctuation and hence, in such cases, the buoys are not steady and they do not give correct guidance regarding alignment.
- The presence of buoys also indicates the proximity of places with shallow depth of water.
- Buoys are also classified according to their size, shape, colour, weight, purpose, etc. Brief descriptions of buoyage system, mooring buoys and wreck buoys are given below.

Mooring buoys:

- In harbour interiors, buoys are pro vided in fixed positions to which ships could be moored during their stay in the harbour without using anchors.
- These buoys are called mooring buoys. Some common types of mooring buoys in use in India are shown in fig.

Wreck buoys:

These arc of peculiar shape and are used to locate wrecks in harbour exteriors or open seas. They are also used for sea cable crossing locations

Fog signals:

These signals are to be provided at places likely to be seriously affected by fog and they take the following forms:

- Ordinary bells struck by hand.
- Ordinary bells operated by mechanism.
- Submarine bells struck by mechanism.
- Whistles or sirens blown by compressed air or steam.

Audible signals:

- These signals are to be used in emergency to bring immediate attention of the mariners and they take up the form of explosive signals, electric oscillators, sirens, bells and diaphones.
- Thus, audible or sound signals are very useful during heavy mists or fogs. It should also be noted that sound transmitted through the air gives sometimes the misleading idea about the direction of sound.
- Hence, resort is made to submarine sound signals in such a way that they can be heard from a great distance with easy identification of the direction.