SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – I – Railways, Airport and Harbour Engineering – SCIA1701

I. Railway Planning

Development of railways in India - Comparison of roadways and railways - Components of a permanent way and its functions - Rails, Gauges, Sleepers, Ballast, Formation, Rail fittings and fastenings - Coning of wheels - Defects in rails: creep in rails, Track Stress - Gradient and Grade compensation on curves - Speed on curves – Super elevation and Negative super elevation - Maximum Permissible speed on curve (Problems included) - Widening of gauge on curves.

<u>DEVELOPMENT OF RAILWAYS IN INDIA</u>

The history of railway development in India is given in detail below:

History of Railway Development # The Old Guarantee System (1844-69):

The railway construction received “the first decisive stimulus” during Dalhousie’s administration. When Lord Dalhousie anchored in India in 1847, he recommended the policy of constructing trunk lines connecting the interior of each of the three Presidencies instead of the previous policy of constructing experimental lines.

He also recommended that railway construction should be entrusted to private companies **“under the supervision and control of the Government”**. He flatly rejected the idea of Government constructing the railways.

In accordance with Dalhousie’s plan, contracts were made with eight companies for the construction and management of 5,000 miles of railway line between 1854 and 1860 under terms that came to be known as the Old Guarantee System (OGS).

Features of the OGS:

1) Free gift of land by the State to the private companies on a lease for 99 years;
2) Guaranteed interest at rates varying between 5 p.c. and 4.5 p.c. on the capital outlay payable at the fixed rate of exchange of 22 pence per rupee for a period of 99 years on the capital raised by the companies;
3) Surplus profits over this 5 p.c., if any, were to be shared equally with the Government;
4) (iv)Reservation of powers of supervision and control of the construction and the working of the railways including rates and fares by the Government;
5) Reservation of the right of purchase of lines after 25 years by the State;

6) Surrender of the railroads at 6 months' notice by the companies and get back the actual capital spent by them, if they wished.

History of Railway Development # State Construction and Management (1869-82):

In view of the extravagance and mismanagement of the private companies, absence of effective control in the working of the companies, the remote possibilities of sharing the profits and highly unsatisfactory financial results, it was decided to follow a policy of direct government construction of railways. So far as the OGS was concerned, the entire profits, went to the foreign companies while the entire loss to the Government.

The then Viceroy, Governor General Lord Lawrence, in 1867 and, again, in 1869, argued that the Government of India could raise capital in the British market at a cheaper rate (e.g., not more than 4 p.c.) and undertake the cheaper methods of construction of railways under its own supervision.

History of Railway Development # The New Guarantee System (1882-1900):

The Parliamentary Select Committee of 1884 recommended that, along with the private companies, the 'State' should come forward to construct railways. Thus, this arrangement — known as the New Guarantee System (NGS)— was based on a sort of partnership between the Government and the private railway companies. Under this system, fresh contracts were made by the Government with the private companies, but with terms more favorable to itself this time.

The chief differentiating features of the NGS were:

1) Railway lines managed by private companies from the beginning were declared to be the property of the Secretary of State for India who reserved the right to terminate the contract after 25 years and/or at subsequent 10-year intervals on payment of the capital provided by the companies;
2) The interest guaranteed to the companies on their capital was pegged at a lower rate, usually 3.5 p.c.; and
3) The Government retained a much larger share of the surplus profits, usually three-fifths.

History of Railway Development # Rapid Extension of Railways up to 1914:

With the advent of the 20th century, Indian railways entered a new era. Thanks to the thriving trade and commerce, India became equipped with huge railway network which made railways a **"running concern"**. But problems remained. Railway administration exhibited utter inconsistency since railway lines were classified into at least 10 groups on the basis of ownership and management. Further, the speed of movement of freight and passenger trains was not only slow but also accident-prone. The railway stock was not adapted to the country's requirements.

The following four major aspects emerge from the above historical development of Indian railways:

- Firstly, no purely Indian company was formed for railway construction in India. Instead, guaranteed foreign private companies were allowed with adequate backing. In fact, for all practical purposes, Indian private companies with capital resources played a negligible part in the construction of Indian' railways.
- Secondly, despite being assured or guaranteed interest on capital, private foreign companies lacked initiative and enterprise since they were unwilling to face the normal hazards of enterprise. Companies were hesitant in undertaking 'risks of loss'. These companies intended to be sheltered or protected.
- Thirdly, the speed at which railways were built in India was really remarkable amidst difficulties of multifarious nature—resource crunch, plague, famines, etc. Even in England, railway development lagged behind India.
- Finally, despite the guarantee clause, Indian railways failed to meet the interest charges on the capital invested in them until the close of the 19th century. Up to 1900, when Indian railways saw the 'face' of net profit, the Government had to shoulder the enormous burden of Rs. 76 crore on account of guaranteed interest.

History of Railway Development # The World War I: Breakdown of the Railway System (1914-21):

The World War I brought utter chaos and confusion, thereby exposing the weaknesses of the Indian railway system. During this time railways came under obligation to carry troops and stores. Capital expenditure had been drastically reduced from Rs. 18.4 crore in 1913-14 to Rs. 2.97 crore in 1916-17 mainly because of the exigencies of the war finance.

History of Railway Development # The Acworth Committee—Separation of Railway Finance (1921-30):

After the termination of the First World War (1918), the Indian public opinion strongly voted for State management. Consequently, the Indian Railway Committee was appointed in 1920 headed by Sir William Acworth—a railway expert in England.

It was appointed to examine in detail:

1) The advantages of alternative methods of management of State-owned railways,
2) The organisation of the Railway Board and the extent of the Government control over the railway administration, and
3) The future policy of railway finance.

History of Railway Development # The Great Depression and after (1929-39):

The Great Depression dealt a body blow to India's agricultural economy. Under its brutal impact, exports of agricultural raw materials showed; a remarkable decline and, consequently, railway traffic plummeted down. The freight carried by railways declined from 91 million tons in 1928-29 to 71 million tons and passenger traffic from 634 million to 480 million in 1932-33.

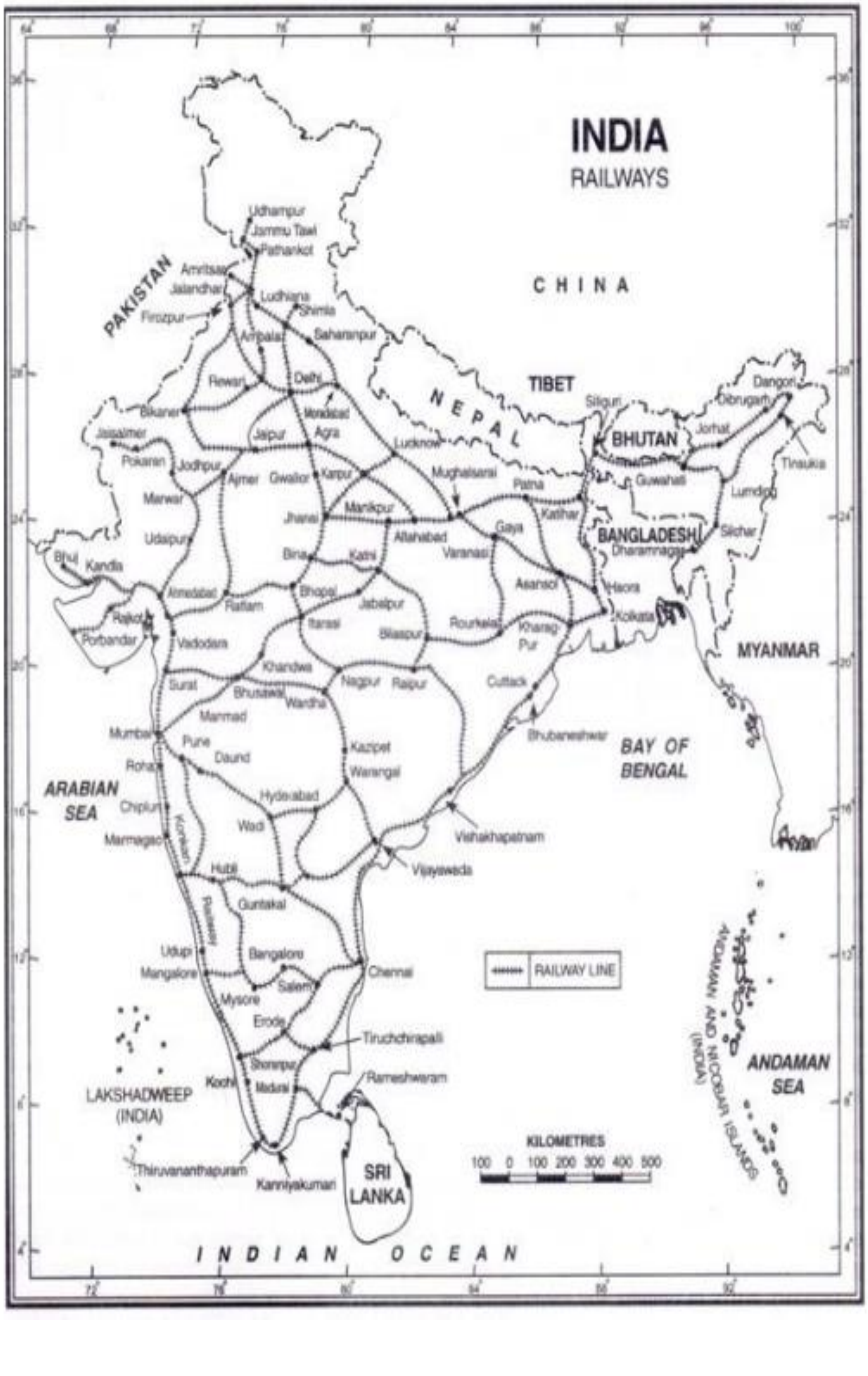
History of Railway Development # From World War II to Partition (1939-1947):

Works relating to maintenance and renewals except the most essential were shelved due to the exigencies of the war. In addition, track, rolling stock and other supplies had to be bodily removed for use in the Middle East theatres of war. All these led to severe strain on the railways.

However, the period was marked by financial prosperity. Gross earnings rose from Rs. 94 crore in 1938-39 to Rs. 226 crore in 1945-46. Railways' contribution to the general revenues came to Rs. 158 crore and the railway Reserve Fund increased by Rs. 76 crore over the same period.

Distribution of Indian Railways:

The following figure shows distribution pattern of Indian railways


INDIA
RAILWAYS
CHINA
TIBET
NEPAL
PAKISTAN
BHUTAN
BANGLADESH
MYANMAR
BAY OF BENGAL
ARABIAN SEA
ANDAMAN SEA
INDIAN OCEAN
SRI LANKA
LAKSHADWEEP (INDIA)
ANDAMAN AND NICOBAR ISLANDS (INDIA)
RAILWAY LINE
KILOMETRES
100 0 100 200 300 400 500
Udhampur
Jammu Tawi
Pathankot
Amritsar
Jalandhar
Firozpur
Ludhiana
Shimla
Ambala
Saharanpur
Rewari
Delhi
Bikaner
Jaisalmer
Pokaran
Jodhpur
Ajmer
Jaipur
Agra
Gwalior
Lucknow
Mughalsarai
Patna
Marwar
Udaipur
Jhansi
Manikpur
Allahabad
Varanasi
Gaya
Katihar
Siliguri
Guwahati
Jorhat
Dibrugarh
Tinsukia
Lumding
Silchar
Bhuj
Kandla
Rajkot
Porbandar
Ahmedabad
Ratlam
Bhopal
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Bilaspur
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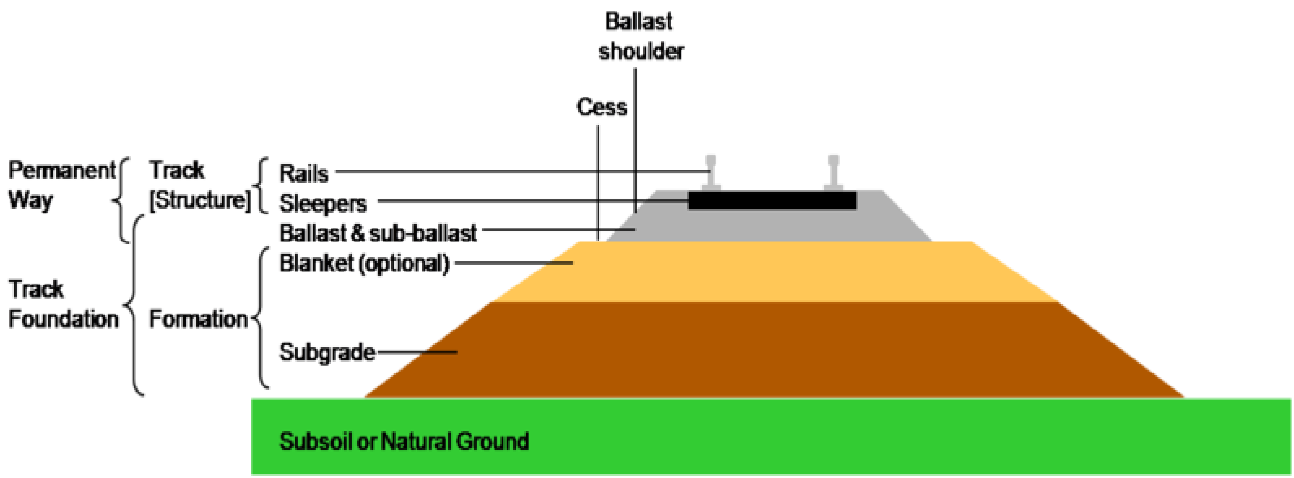
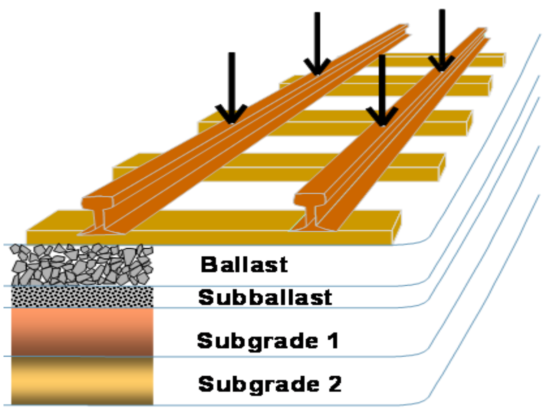
Wardha
Nagpur
Raipur
Cuttack
Bhubaneshwar
Mumbai
Manmad
Pune
Daund
Kazipet
Warangal
Hyderabad
Wadi
Chiplun
Marmagao
Vishakhapatnam
Vijayawada
Hubli
Guntakal
Udupi
Mangalore
Bangalore
Chennai
Mysore
Salem
Erode
Tiruchchirapalli
Kochi
Madurai
Rameshwaram
Thiruvananthapuram
Kanniyakumari

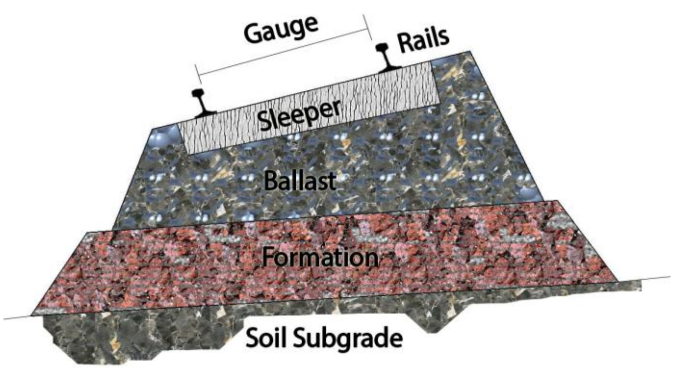
COMPARISON OF RAILWAYS AND ROADWAYS

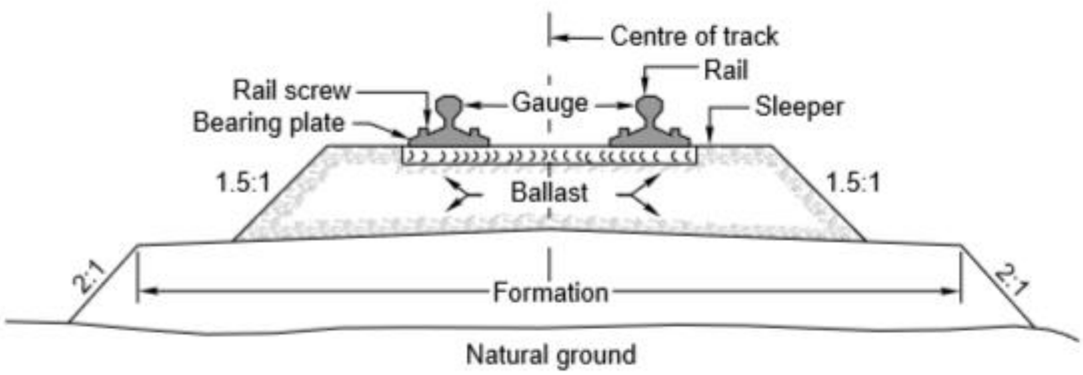
Feature	*Rail transport*	*Road transport*
Tractive resistance	The movement of steel wheels on steel rails has the basic advantage of low rolling resistance. This reduces haulage costs because of low tractive resistance.	The tractive resistance of a pneumatic tyre on metalled roads is almost five times compared to that of wheels on rails.
Right of way	A railway track is defined on two rails and is within protected limits. Trains work as per a prescribed schedule and no other vehicle has the right of way except at specified level crossings.	Roads, though having well-defined limits, can be used by any vehicular traffic and even by pedestrians they are open to all.
Cost analysis	Owing to the heavy infrastructure, the initial as well as maintenance cost of a railway line is high	The cost of construction and maintenance of roads is comparatively cheaper.
Gradients and Curves	The gradients of railways tracks are flatter (normally not more than 1 in 100) and curves are limited up to only 10° on broad gauge.	Roads are constructed normally with steeper gradients of up to 1 in 30 and relatively much sharper curves.
Flexibility of movement	Due to the defined routes and facilities required for the reception and dispatch of trains, railways can be used only between fixed points.	Road transports have much more flexibility in movement and can provide door-to-door services.
Environment pollution	Railways have minimum adverse effects on the environment.	Road transport creates comparatively greater pollution than the railways.
Organization and control	Railways are government undertakings, with their own organization.	Barring member state government transport, road transport is managed by the private sector.
Suitability	Railways are best suited for carrying heavy goods and large numbers of passengers over long distances.	Road transport is best suited for carrying lighter goods and smaller numbers of passengers over shorter distances.

COMPONENTS OF A PERMANENT WAY









RAILS

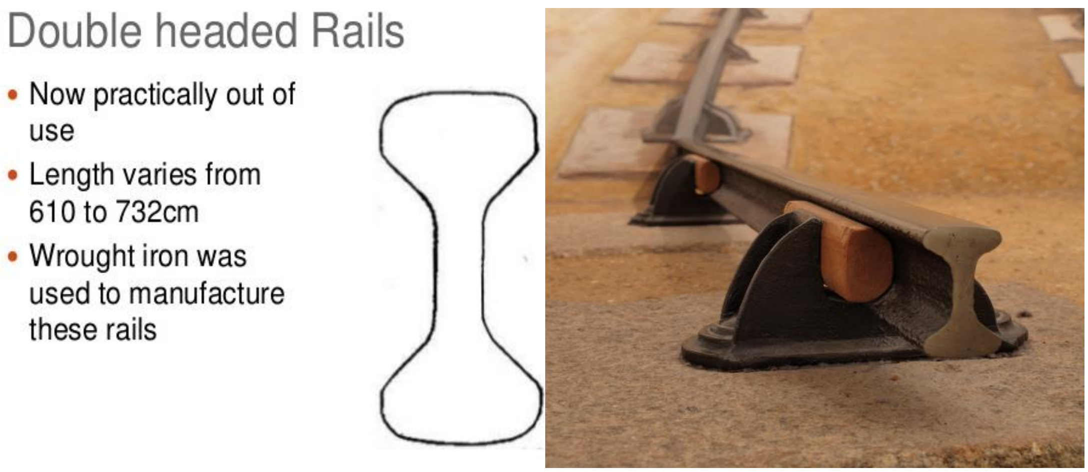
Rails are the I-section members of a track laid in two parallel lines to provide a level surface for the movement of trains.

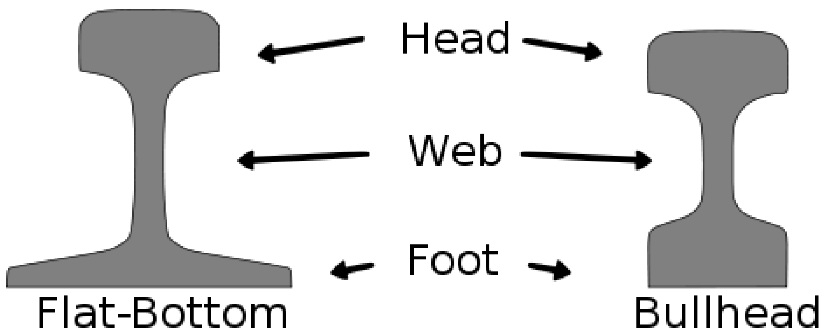
Function of Rails

- To provide a continuous and level surface for the movement of trains.
- To serve as a lateral guide for the wheels.
- To transmit the load to a large area of the formation through sleepers and ballast.
- To bear the stresses developed due to vertical loads transmitted to them.

Types of Rails

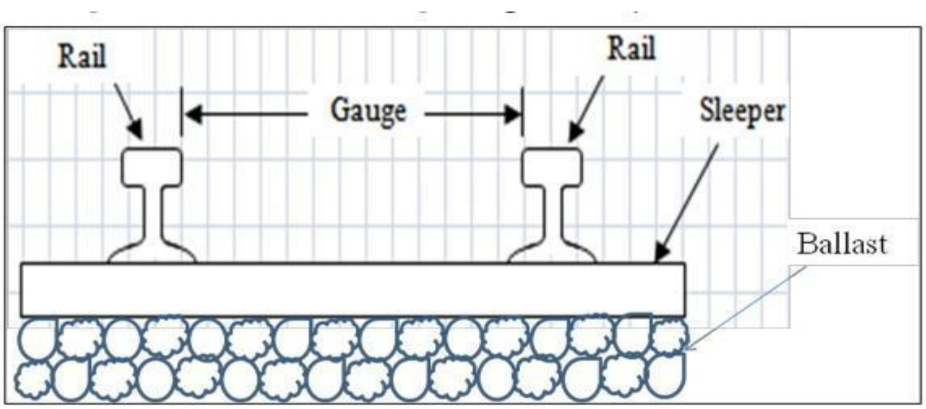
- Double Headed Rail
- Bull Headed Rail
- Flat-footed Rail






Track Gauge

As per Indian Railways, it is the clear minimum distance between the running faces of two rails.



Standard Rail Sections:

Name of the Gauge	Width (m)
Broad Gauge (B.G.)	1.676
Meter Gauge (M.G.)	1.000
Narrow gauge (N.G.)	0.762

Name of the Gauge	Length (m)
Broad Gauge (B.G.)	13
Meter Gauge (M.G.)	12
Narrow gauge (N.G.)	12

<u>SLEEPERS</u>

Sleepers are the transverse ties laid to support the rails.

Function of Sleepers

- To hold the rails in their correct gauge and alignment

- To give a firm and even support to the rails
- To transfer the load evenly from the rails to a wider area.
- To provide the longitudinal and lateral stability to the permanent way.
- To act as a elastic medium between the rails and the ballast to absorb the vibrations caused by wheel loads.

TYPES OF SLEEPERS

Depending upon the position in a railway track, railway sleepers may be classified as:

1. Longitudinal Sleepers
2. Transverse Sleepers

1. Longitudinal Sleepers

These are the early form of sleepers which are not commonly used nowadays. It consists of slabs of stones or pieces of woods placed parallel to and underneath the rails. To maintain correct gauge of the track, cross pieces are provided at regular intervals.

At present this type of sleepers are discarded mainly because of the following reasons.

- Running of the train is not smooth when this type of sleepers is used.
- Noise created by the track is considerable.
- Cost is high.

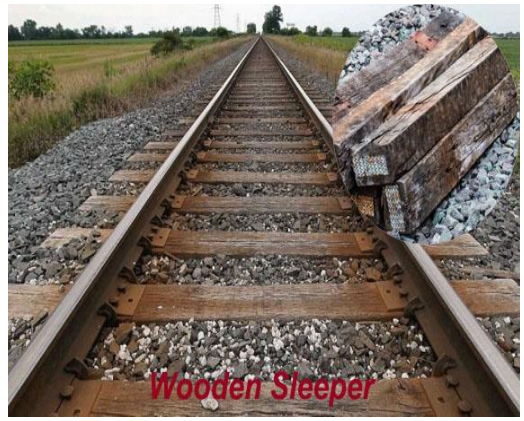
2. Transverse Sleepers

Transverse sleepers introduced in 1835 and since then they are universally used. They remove the drawbacks of longitudinal sleepers i.e. the transverse sleepers are economical, silent in operation and running of the train over these sleepers is smooth. Depending upon the material, the transverse sleepers may be classified as:

- Timber/wooden sleepers
- Steel sleepers
- Cast Iron Sleepers
- Concrete Sleepers

Timber or Wooden Sleepers

The timber sleepers nearly fulfilled all the requirements of ideal sleepers and hence they are universally used. The wood used may be like teak, sal etc or it may be coniferous like pine.



The salient features of timber/wooden sleepers with advantages and disadvantages.

Advantages of Timber Sleepers

- They are much useful for heavy loads and high speeds
- They have long life of 10-12 years depending upon the climate, condition, rain, intensity, nature of traffic, quality of wood etc
- Good insulators and hence good for track circuited railway tracks
- They are able to accommodate any gauge
- Suitable for salty regions and coastal areas
- Can be used with any section of rail
- Can be handled and placed easily
- They are not badly damaged in case of derailment
- They are not corroded
- Cheaper than any other types of sleepers

Disadvantages of Timber Sleepers

- Liable to be attacked by vermin so, they must be properly treated before use
- Liable to catch fire
- They do not resist creep
- They are affected by dry and wet rot
- Become expensive day by day
- Life is shorter compare to others

Steel sleepers

They are in the form of steel trough inverted on which rails are fixed directly by keys or nuts and bolts and used along sufficient length of tracks.

Advantages of Steel Sleepers

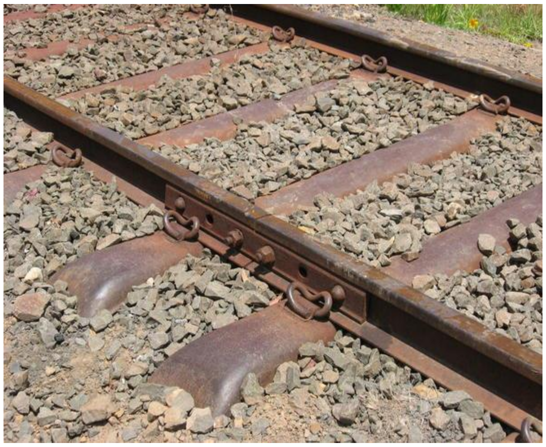
- Have a useful life of 20-25 years.
- Free from decay and are not attacked by vermins
- Connection between rail and sleeper is stronger
- Connection between rail and sleeper is simple
- More attention is not required after laying
- Having better lateral rigidity
- Good scrap value
- Suitable for high speeds and load
- Easy to handle
- Good resistance against creep

Disadvantages of Steel sleepers

- Liable to corrosion by moisture and should not because in salty regions
- Good insulators and hence cannot be used in track circuited regions
- Cannot be used for all sections of rails and gauges
- Should not be laid with any other types of ballast except store
- Very costly
- Can badly damaged under derailments
- Way gauge is obtained if the keys are over driven
- The rail seat is weaker
- Having good shock absorber as there is not cushion between rail foot and ballast

Cast Iron Sleepers

They consist of two pots or plates with rib and connected by wrought iron tie bar of section of about 2″ ½” each pot or plate is placed below each rail. The pot is oval in shape with larger diameter 2′-0″ and smaller diameter 1′-8″ is preferred. Plate sleepers consist of rectangular plates of size about 2′ – 10′ x 1′ – 0″.

The relative advantages and disadvantages are given below.

Advantages of Cast Iron Sleepers

- Long life upto 50-60 years
- High scrape value as they can be remolded
- Can be manufactured locally
- Provided sufficient bearing area
- Much stronger at the rail seat
- Prevent and check creep of rail
- They are not attacked by vermin

Disadvantages Cast Iron Sleepers

- They are prone to corrosion and cannot be used in salty formations and coastal areas
- Not suitable for track circuited portions of railways
- Can badly damage under derailment
- Difficult to maintain the gauge as the two pots are independent
- Require a large number of fastening materials
- Difficult to handle and may be easily damaged
- Lack of good shock absorber
- They are expensive

Concrete sleepers

R.C.C and pre-stressed concrete sleepers are now replacing all other types of sleepers except to some special circumstances such as crossing bridges etc here timber sleepers are used. They were first of all used in France round about in 1914 but are common since 1950. They may be a twin block sleepers joined by an angle iron. It may be a single block pre-stressed type.

Advantages Concrete Sleepers

- Durable with life range from 40-50 years
- They can be produced on large quantities locally by installing a plant
- Heavier than all other types thus giving better lateral stability to the track
- Good insulators and thus suitable for use in track circuited lines
- Efficient in controlling creep
- They are not attacked by corrosion
- Free from attacks of vermin and decay, suitable for all types of soils
- Most suitable for welded tracks
- Prevent buckling more efficiently
- Initial cost is high but proves to be economical in long run
- Effectively and strongly hold the track to gauge
- Inflammable and fire resistant

Disadvantages Concrete Sleepers

- Difficult to be handled
- Difficult to be manufactured in different sizes thus cannot be used in bridges and crossing
- Can be damaged easily while loading and unloading

Sleeper Density - Number of Sleepers per unit length.		
Sleeper Density	=	(M+x) or (N+x)
Where M or N	=	length of Rail in m

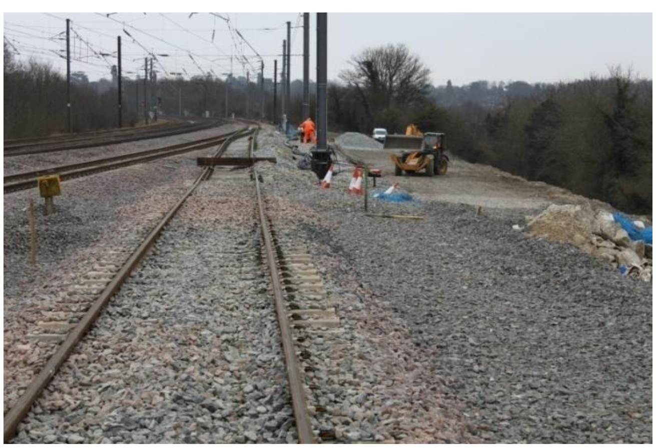
X	=	Number which depends on factors such as Axle load and speed Type and section of rails Type and Strength of Sleepers Type of Ballast and depth of ballast cushion Nature of formation

<u>Comparison of different types of sleepers</u>

Characteristics	Type of Sleeper			
	Wooden	**Steel**	**Cast Iron**	**Concrete**
Service life (Years)	Dec-15	40-50	40-50	50-60
Weight (Kg)	83	79	87	267
. Maintenance Cost	High	Medium	Medium	Low
Gauge Adjustment	Difficult	Easy	Easy	No Gauge Adjustment possible
Track Circuiting	Best	Difficult	Difficult	Easy
Scrap Value	Low	Higher than Wood	High	No Scrap Value

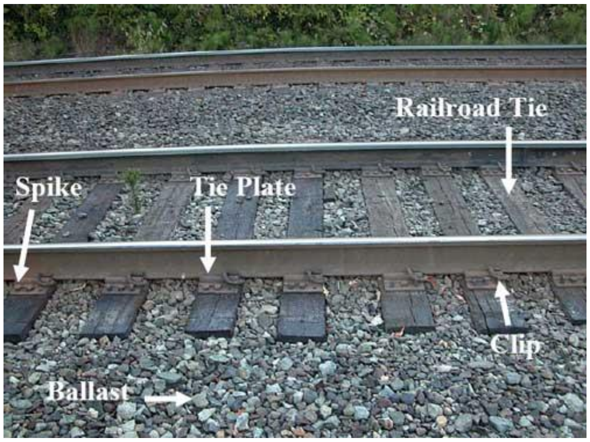
<u>BALLAST</u>

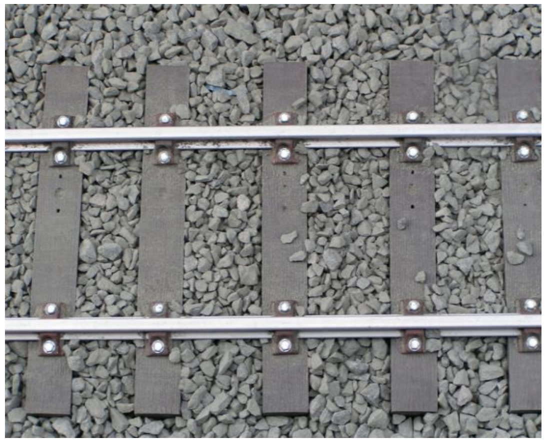
Layer of broken stones, gravel, moorum or any other granular material placed and packed below and around sleepers.



Functions of Ballast

- Provides a level and hard bed for the sleepers to rest on.
- Holds the sleepers in position.
- Transfers and distributes load from the sleepers to a large area of the formation.
- Provides effective drainage of the track.
- Provides elasticity and resilience to the track for proper riding comfort.





Types of Ballast

Types of Ballast	Advantages	Disadvantages	Suitability
Sand Ballast	Good Drainage properties Cheap	Causes Excessive wear Blows off easily	Suitable for CI pot sleeper tracks
Moorum Ballast	Prevents water from percolating Cheap, if locally available	Very soft and turns into dust	Used as a sub-ballast Initial Ballast for new construction
Coal Ash or Cinder	Easily available Cheap	Harmful for steel sleepers Corrodes rail bottom and steel sleepers	Used in yards and sidings
Broken Stone Ballast	Hard and Durable Economical in the long run	Initial cost is high	Used for high speed tracks

Sand ballast *Gravel Ballast*

Brickbat Ballast

Coal Ash Ballast *Broken Stone Ballast*

Other types of Ballast

- Brickbat Ballast
- Gravel Ballast
- Kankar Stone Ballast
- Earth Ballast

Collection and Transportation of Ballast

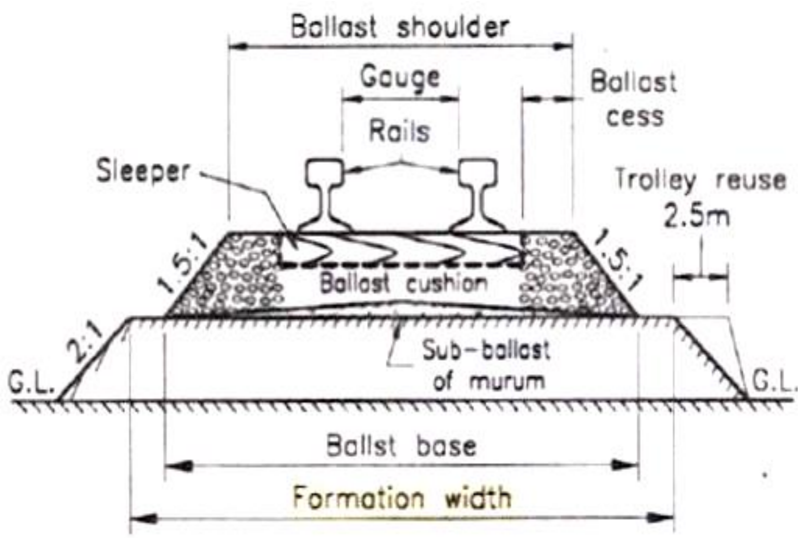
- Collecting the ballast at ballast depots and transporting it to the site in ballast trains
- Collecting the ballast along the cess and placing the ballast on the track directly.

SUBGRADE and FORMATION

Subgrade is a naturally occurring soil which is prepared to receive the ballast. Formation is the prepared flat surface which is ready to receive the ballast along with sleepers and rails.

Functions of formation

- Provides a smooth and uniform bed for laying the track
- Bears the load transmitted to it from the moving load through the ballast
- Facilitates the drainage
- Provides the stability to the track



Width of formation of different tracks

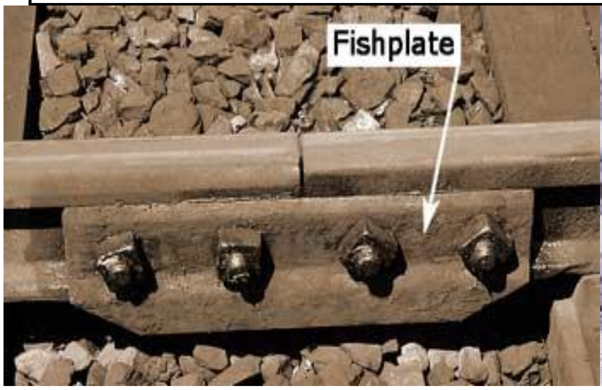
Gauge	Single - line section		Double – line section	
	Width of embankment (m)	Width of cutting (m)	Width of embankment (m)	Width of cutting (m)
B.G.	6.85	6.25	12.155	11.555
M.G.	5.85	5.25	9.81	9.21
N.G.	3.70	3.35	7.32	7.01

RAIL FITTINGS AND FASTENINGS

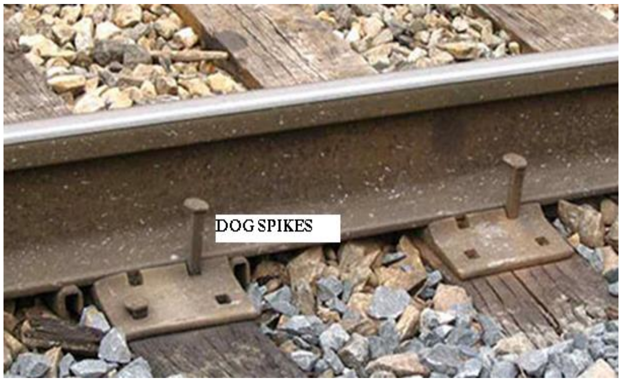
- To hold the rails in their proper position in order to ensure the smooth running of trains.
- To join the rails together as well as fixing them with sleepers.

Types of Fittings and Fastenings

Purpose	**Types of Fittings and Fastenings**
Joining rail to rail	Fish plates, bolts and nuts
Joining rail to wooden sleepers	Dog spikes, screw spikes and bearing plates
Joining rail to steel sleepers	Loose jaws, keys and liners
Joining rail to cast iron sleepers	Tie bars and cotters
Elastic fastenings	Elastic or Pandrol clip

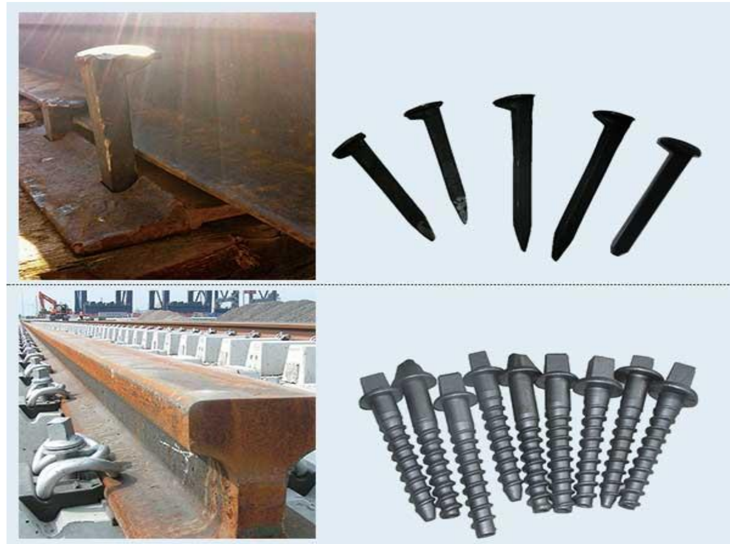


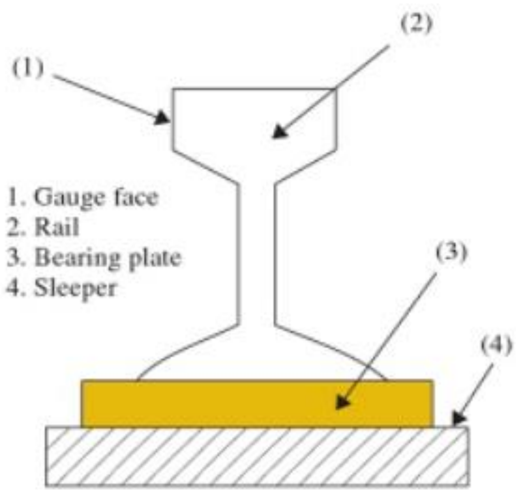
Fish Plates, Nuts and Bolts



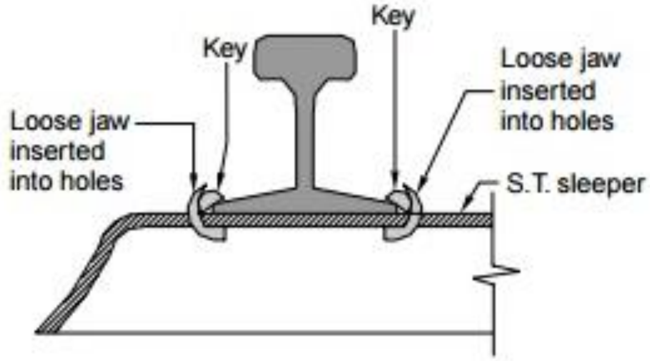
Dog Spikes

Screw Spikes

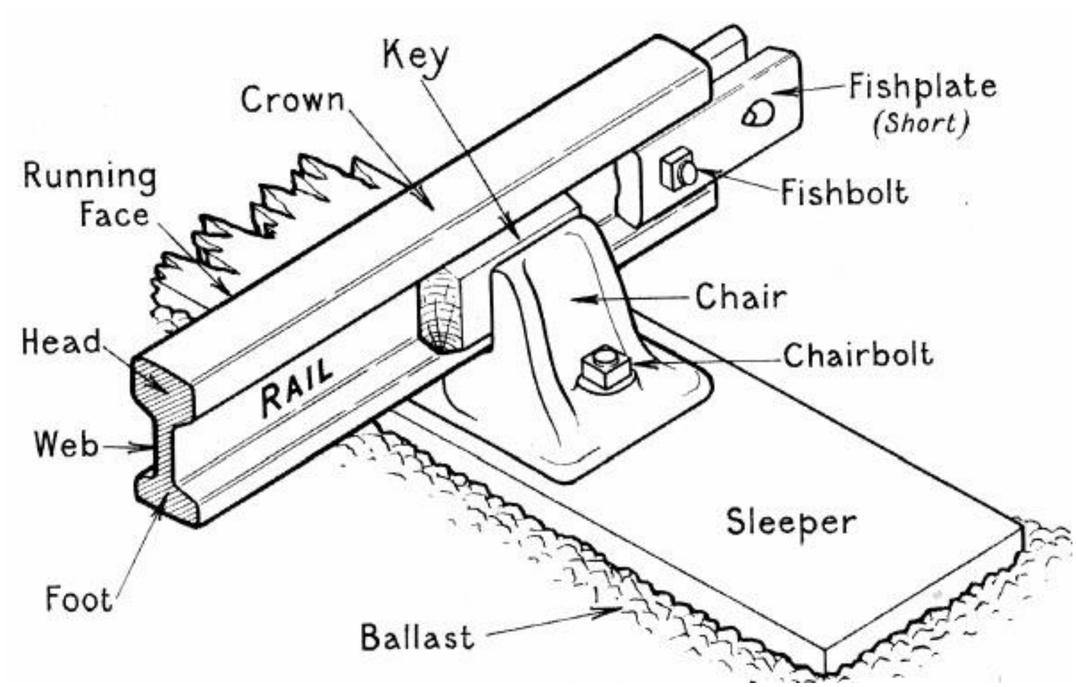




Bearing Plate



Loose Jaws, keys and liners in tracks



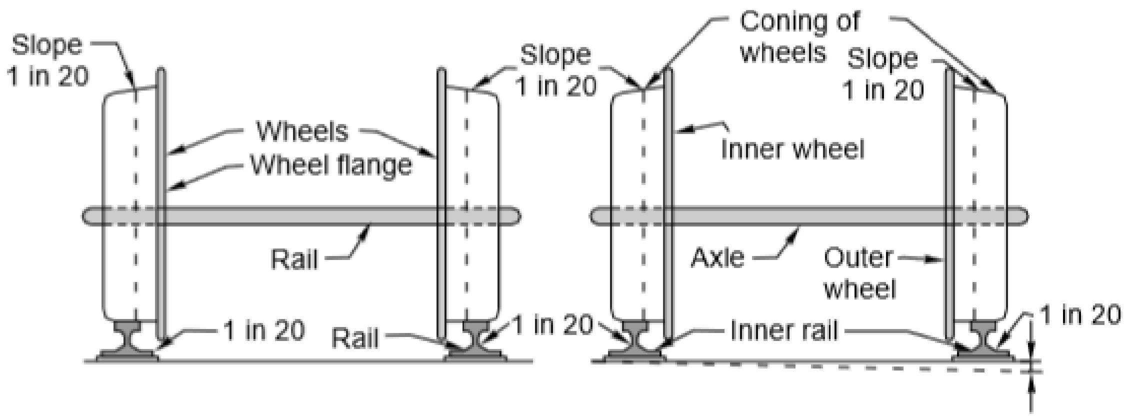
Pandrol clip fixed to rail seat

Pandrol clip

CONING OF WHEELS

The rim or flanges of the wheels are never made flat but they are in the shape of a cone with a slope of about 1 to 20. This is known as coning of wheels. The coning of wheels is manly done to maintain the vehicle in the central position with respect to the track. When the vehicle is moving on leveled track then the flanges of wheels have equal circumference.

But when the vehicle is moving along a curved path then in this case the outer wheel has to cover a greater distance then that of inner wheel. Also as the vehicle has a tendency to move sideways towards the outer rail, the circumferences of the flanges of the inner wheel and this will help the outer wheel to cover a longer distance than the inner wheel. In this ways smooth riding is produced by means of coning of wheels.



Advantages of Tilting of Rails

1. It maintains the gauge properly.
2. The wear at the head of rail is uniform.
3. It increases the life of sleepers and the rails.

Coning wheels has the following disadvantages

1. In order to minimize the above below disadvantages the tilting of rails is done. i.e. the rails are not laid flat but tilted inwards by using inclined base plates sloped at 1 in 20 which is also the slope of coned surface of wheels.
2. The pressure of the horizontal component near the inner edge of the rail has a tendency to wear the rail quickly.
3. The horizontal components tend to turn the rail outwardly and hence the gauge is widened sometimes.
4. If no base plates are provided, sleepers under the outer edge of the rails are damaged.
5. In order to minimize the above mentioned disadvantages the tilting of rails is done. i.e. the rails are not laid flat but tilted inwards by using inclined base plates sloped at 1 in 20 which is also the slope of coned surface of wheels.

DEFECTS IN RAILS

Nature of defects in rails;

1. Horizontal crack in head: These cracks run usually parallel to the rail table at a depth of 10-20 mm and may finally split the material layer.
2. Vertical-longitudinal split in head: These cracks run parallel to the longitudinal axis of the rail and are caused by presence of non-metallic inclusions, poor maintenance of joints and high dynamic stresses. It cannot be easily detected in early stages by USFD due to their unfavorable orientation.
3. Horizontal crack at head web junction: causes are wheel flats, bad fish-plated joint, inclusions and high residual stresses.
4. Horizontal crack at web-foot junction: Such cracks develop both towards head and foot. They are caused by high vertical and lateral dynamic loads, scoring and high residual stresses.
5. Vertical longitudinal splitting of the web: It is primarily due to heavy accumulation of non-metallic inclusions and wheel flats. Vertical longitudinal defects of minor nature are not amenable to USFD examination conducted from rail top.
6. Bolt hole crack: Such cracks often run diagonally and may run towards head or the foot. They result from inadequately maintained joints and unchamfered fish bolt holes and stress concentration.
7. Transverse fracture without apparent origin: These fractures occur suddenly, especially during winter and may emanate from microscopic flaws (embedded or on surface) and are generally very difficult to detect by USFD. These minute flaws manifest suddenly under severe service conditions or when the fracture toughness values are comparatively low.
8. Transverse fatigue crack in head: They resemble a kidney in shape in the railhead and USFD is ideally suited for detecting them. They are generally inclined at the angle of 18 deg -23 deg and originate at a depth of 15-20 mm below the running surface. Mainly hydrogen accumulation and non-metallic inclusions cause this defect. These cracks are easily detected by 70 deg probe. When such defects are nearly vertical, they can be detected using additional gain of 10db.
9. Horizontal crack at top and bottom fillet radius: These cracks are caused by accumulation of non-metallic inclusions and high residual stresses introduced at the time of rail straightening. These are difficult to be detected by USFD.
10. Vertical – longitudinal crack in foot: cracks develop from sharp chamfers on the bottom surface of the rail foot. Cracks occurring in this way are the points of origin of transverse cracks in the foot.
11. Transverse cracks in rail foot: Due to localized overheating during FB welding, structural changes in the bottom surface of the rail material takes place which result in a minor crack. These cracks under the tensile loading give rise to brittle fracture. Such defects are not detectable by USFD.

CREEP IN RAILS

Creep in rail is defined as the longitudinal movement of the rails in the track in the direction of motion of locomotives. Creep is common to all railways and its value varies from almost nothing to about 6 inches or 16cm.

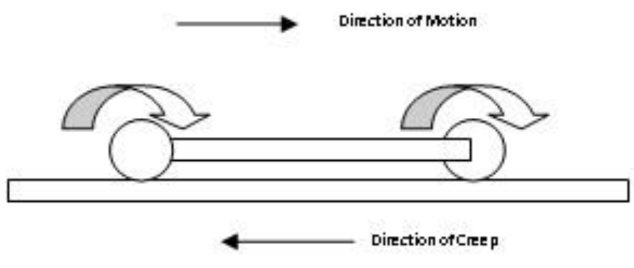
Causes of Creep

The causes of rail creep can be broadly classified into two categories

1. Major Causes o Creep
2. Minor Causes of Creep

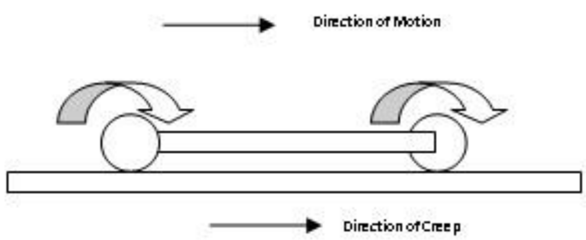
Major causes of creep are also known as principal causes of creep. Follows are the major causes of creep in rail

1. Creep may be developed due to forces that come into operation when the train is starting or stopping by application of brakes. Increase of starting the wheels pushes the rail backward and hence the direction of creep is in backward direction.



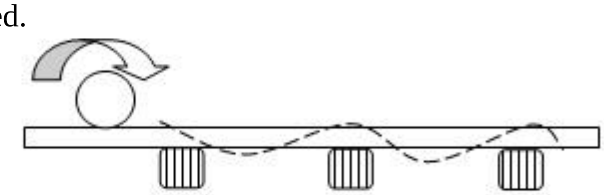
Train Starting Point

When brakes are applied then the wheels of the vehicles push the rails in forward direction and hence the creep is in forward direction.



Train Stopping Point

2. Creep is also developed due to wave motions. When the wheels of the vehicles strike the crests, creep is developed.



3. Another reason creep develops because of unequal expansion and contraction owing to change in temperature.

Minor Causes Creep

Some of the minor causes of creep in rail are below:

1. Rails not properly fixed to sleepers
2. Bad drainage of ballast
3. Bad quality of sleepers used
4. Improper consolidation of formation bed
5. Gauge fixed too tight or too slack
6. Rails fixed too tight to carry the traffic
7. Incorrect adjustment of super elevation on outer rails at curves
8. Incorrect allowance for rails expansion
9. Rail joints maintained in bad condition

Effects of Creep

The following are the common effects of creep.

- **Sleepers out of square** The sleepers move out of their position as a result of creep and become out of square. This in turn affects the gauge and alignment of the track, which finally results in unpleasant rides.
- **Disturbance in gaps get disturbed** Due to creep, the expansion gaps widen at some places and close at others. This results in the joints getting jammed. Undue stresses are created in the fish plates and bolts, which affects the smooth working of the switch expansion joints in the case of long welded rails.
- **Distortion of points and crossings** Due to excessive creep, it becomes difficult to maintain the correct gauge and alignment of the rails at points and crossings.
- **Difficulty in changing rails** If, due to operational reasons, it is required that the rail be changed, the same becomes difficult as the new rail is found to be either too short or too long because of creep.
- **Effect on interlocking** The interlocking mechanism of the points and crossings gets disturbed by creep.
- **Possible buckling of track** If the creep is excessive and there is negligence in the maintenance of the track, the possibility of buckling of the track cannot be ruled out.
- **Other effects** There are other miscellaneous effects of creep such as breaking of bolts and kinks in the alignment, which occur in various situations.

Magnitude and Direction of Creep

Creep is not constant over a given period; it is not continue in one direction or at uniform rate. Both the rails of the track may creep in same direction, perhaps both the rails reverse the direction of creep or one rail creep in opposite direction to that of other. In other words, the direction and magnitude of creep cannot be predicted.

Following are some of the items governing the direction and magnitude of creep

1. Alignment of Track - Creep is found to be greater on curves than on straights.

2. Grade of Track - Rails normally creep in the direction of downgrade through the creep in reverse direction i.e. upgrade is also possible.

3. Direction of Heavy Traffic - If heavy or loaded vehicles run in one direction and the empty train move in opposite direction then the creep is founded to be in the direction of loaded trains.

Results and Consequences of Creep

Following are some of the undesirable consequences of creep

1. The most serious effect of creep is the buckling of track in lateral directions. If unattended and not properly removed then it causes derailments which leads to accidents.
2. Sleepers do not remain at fixed position and then gauges of the track are disturbed. The alignment and rail level is also disturbed. This causes bad running of trains.
3. It becomes difficult to fix the rails with creep. It is found either too short or too long due to creep.
4. The gaps are widened at some places while closer at some places. This causes undue stresses.
5. The location of points and crossings is disturbed and it is difficult to keep correct gauge and the alignment.
6. The interlocking mechanism is also disturbed due to creep in rails.

Methods for Correction of Creep

There are two methods used for the correction of creep. These are

1. Pulling back Method
2. Use of Creep Anchors / Anti Creepers

1. Pulling Back Method

In pulling back method the effects of creep are observed during ordinary maintenance of track. Then the rails are pulled back equal to the amount of creep, either by manpower or by the use of jacks. For this purpose, the sleeper fittings are made loose, the fish bolts at one end of the rail are removed while at the other end they are made loose. The liner of required size is interested in the gap and the rails are pushed or pulled as required.

Pushing is done by inserting short length of rod through bolt hole and then pushing the rail forward by means of a crow bar. Pulling is done by inserting hook through the bolt hole and then hauling the bolt hole by means of a rope attained to it.

Following points should be kept in mind in correction of creep

1. The track below sleepers should be properly packed after pulling and pushing operations.
2. The small pieces of rails should always be kept ready during progress of work to allow passage of trains at low restricted speeds.
3. The number of labors required depend upon the nature of creep, number of sleepers affected due to creep.
4. All the fish bolts should be removed, cleaned and oiled and then refixed and tightened up after the rails are brought to their proper positions by pushing or pulling.
5. The anchors, if to be installed, should be fixed after this process.

2. Use of Creep Anchors (or) Anti Creepers

In this method, specially constructed device known as creep anchors or anti creepers are used. It consists of cast iron pieces used to grip the rails. Creep anchors are provided behind the sleepers for every third or fourth sleepers.

This arrangement prevents the movement of rails because the sleepers which are embedded in the ballast will also have to move if the creep has to take place. This method of reducing creep is quite efficient and economical as it reduces the cost to the extent of about 75% to that of pulling back method.

Various types and makes of patented creep anchors have been constructed and are in use and most of them are found considerably effective.

The following points should be kept in mind in case of creep anchors

1. The creep anchors should be strong enough to resist the stresses produced due to creep.
2. The number of creep anchors per rail length should be determined by intensity of creep.
3. The creep anchors should be provided at a place where creep originates and not alone where the results of creep anchors are most apparent.
4. It should be remembered that the creep anchors should not be provided over railway bridges as far as possible. It is better to provide sufficient number of creep anchors to arrest the creep before it reaches a bridge.

TRACK STRESS

Stresses on the track due to the various kinds of forces applied on it are discussed in the following sections.

Lateral forces

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

Longitudinal forces

Due to the tractive effort of the locomotive and its braking force, longitudinal stresses are developed in the rail. Temperature variations, particularly in welded rails, result in thermal forces, which also lead to the development of stresses. The exact magnitude of longitudinal forces depends on many variable factors. However, a rough idea of these values is as follows:

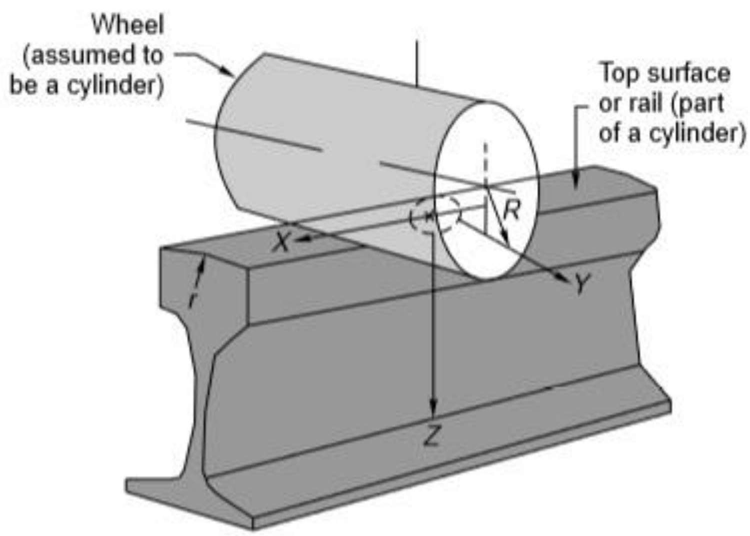
(a) Longitudinal forces on account of 30–40% weight of locomotive of tractive effort for alternating current (ac).

(b) Longitudinal forces on account of 15–20% of weight of braking force of the locomotive and 10–15% weight of trailing load.

Tensile stresses are induced in winter due to contraction and compressive stresses are developed in summer due to compression. The extreme value of these stresses can be 10.75 kg/mm2 in winter and 9.5 kg/mm^2 in summer.

Contact stresses between rail and wheel

Hertz formulated a theory to determine the area of contact and the pressure distribution at the surface of contact between the rail and the wheel. As per this theory, the rail and wheel contact is similar to that of two cylinders (the circular wheel and the curved head of the rail) with their axes at right angles to each other. The area of contact between the two surfaces is bound by an ellipse as shown in Figure below.



The maximum contact shear stress (F) at the contact point between the wheel and the rail is given by the empirical formula

$$F = 4.13*(P/R)^{1/2}$$

Where,

F is the maximum shear stress in kg/mm^2,

R is the radius of the fully worn out wheel in mm, and

P is the static wheel load in kg + 1000 kg for on-loading on curves

Surface defects

A flat on the wheel or a low spot on the rail causes extra stresses on the rail section. Empirical studies reveal that an additional deflection of about 1.5 times the depth of the flat or low spot occurs at the critical speed (about 30 km/h). Additional bending moment is caused on this account with a value of about 370,000 kg cm for the BG group A route with the WDM4 locomotive.

Stresses on a sleeper

The sleepers are subjected to a large number of forces such as dead and live loads, dynamic components of tracks such as rails and sleeper fastenings, maintenance standards, and other such allied factors. Based on the elastic theory, the maximum load on a rail seat is given by the following formula:

$$\text{Maximum load on rail seat} = \frac{P}{Z\mu l}\mu S = \frac{PS}{Zl}$$

Where,

P is the wheel load,

μ is the track modulus,

S is the sleeper spacing,

l is the characteristic length, and

Z is the modulus of the rail section.

The maximum load on the rail seat is 30%–50% of the dynamic wheel load, depending on various factors and particularly the packing under the sleeper. The distribution of load under the sleeper is not easy to determine. The pattern of distribution depends on the sleeper as well as on the firmness of the packing under the sleeper. As the ballast yields under the load, the pressure under the sleeper is not uniform and varies depending on the standard of maintenance. The following two extreme conditions may arise.

End-bound sleeper - The newly compacted ballast is well compacted under the sleeper and the ends of the sleepers are somewhat hard packed. The deflection of the sleeper at the centre is more than that at the ends.

Centre-bound sleeper - As trains pass on the track, the packing under the sleeper tends to become loose because of the hammering action of the moving loads. The sleeper thus tends to be loose under the rail seat. Alternatively, due to defective packing, the sleeper is sometimes hard packed at the centre.

Stresses on ballast

The load passed onto the sleeper from the rail is in turn transferred to the ballast. The efficacy of this load transmission depends not only on the elasticity of the sleeper but also on the size, shape, and depth of the ballast as well as the degree of compaction under the sleeper.

(a) The pressure on the sleeper is maximum at the centre of its width. This pressure decreases from the centre towards the ends.

(b) The vertical pressure under the sleeper is uniform at a depth approximately equal to the spacing between the sleepers.

Pressure on formation or subgrade

The live as well as dead loads exerted by the trains and the superstructure are finally carried by the subgrade. The pressure on the subgrade depends not only on the total quantum of the load but also on the manner in which it is transferred to the subgrade. The spacing between the sleepers; the size, depth, as well as compaction of the ballast under the sleeper; and the type of subgrade play an important role in the distribution of pressure on the subgrade. The values of maximum formation pressure permitted on Indian Railways are the following:

For motive power	3.5 kg/cm^2 for BG
	2.5 kg/cm^2 for MG
For goods wagons	3.0 kg/cm^2 for BG
	2.3 kg/cm^2 for MG

Relief of stresses

A train load consists of a number of wheel loads close to each other which act simultaneously on the rail. A single isolated wheel load creates much more bending moment in the rail as compared to a group of wheel loads, which on account of the negative bending moment under adjacent wheels provide what known as a 'relief of stresses'. The rail stresses in this case are comparatively smaller. The value of relief of stresses depends upon the distance of the point of contra flexure of the rail and the spacing between the wheels, but its value can be as high as 50%.

Permissible stresses on a rail section

The permissible bending stresses due to vertical load and its eccentricity and lateral load on a rail section on Indian Railways is given in table below:

	kg/mm²	*t/in²*
Permissible stress due to bending	36.0	23.00
Minimum ultimate tensile strength	72.0	46.0

The stresses on a rail are measured by any of the following methods depending upon the facilities available.

- *Photo-elastic method*
- *Electric resistance strain gauge method*
- *Method employed using special test frame*

At present, Indian Railways mostly uses the electric resistance strain gauges for measuring rail stresses.

Whenever a new locomotive or rolling stock design is introduced on the Railways, a detailed study is carried out followed by field trials to ensure that the permitted speed of the new locomotive or rolling stock does not cause excessive stresses on the track. The same stipulations are made whenever there is an increase in the speed or axle load of the existing locomotive or rolling stock design.

The various parameters and their limiting values required to be checked for BG are given in table below:

Parameter	*Permissible value*
Bending stress on the rail	36.0 kg/mm^2
Contact stress between the rail and the wheel	21.6 kg/mm^2
Dynamic overloads at rail joints due to unsuspended masses	27 t for locomotives and 19 t for wagons
Formation pressure	3.5 kg/cm^2 for locomotives and 3.0 kg/cm^2 for wagons
Fish plate stresses	30 kg/mm^2
Bolt hole stresses	27 kg/mm^2

GRADIENT AND GRADE COMPENSATION ON CURVES

Gradient

Any departure of track from the level is known as grade or gradient.

Purpose of providing gradient:

- To provide uniform rate of rise or fall,
- To reduce cost of earth work,
- To reach different stations at different level.

Types of gradient

1. ***Ruling gradient*** - The steepest gradient allowed on the track section. It determines the max load that the locomotive can haul that section. The steep gradient needs more powerful locomotives, smaller train loads, lower speed, resulting in costly hauling. –In plains: 1 in 150 to 1 in 200 –In hilly regions: 1 in 100 to 1 in 150
2. ***Momentum Gradient*** - The gradient on a section which are steeper than the ruling gradient acquire sufficient momentum to negotiate them are known as momentum gradient.
3. ***Pusher gradient*** - As stated above a ruling gradient limits the maximum weight of a train which can be hauled over the section by a locomotive. If the ruling gradient is so severe on a section that it needs the help of extra engine to pull the same load than this gradient is known as pusher of helper gradient. In Darjeeling Railways 1 in 37 pusher gradient is used on Western Ghat BG Track.
4. ***Gradient at station -*** At stations gradient are provided sufficient low due to following reason: –To prevent movement of standing vehicle –To prevent additional resistance due to grade. On Indian railways, maximum gradient permitted is 1 in 400 in station yards.

Grade compensation on curves

If a curve is provided on a track with ruling gradient, the resistance of the track will be increased this curve. In order to avoid resistance beyond the allowable limits, the gradients are reduced on curves. The reduction in gradient is known as grade compensation for curves.

- BG track: 0.04% per degree of curve
- MG track: 0.03 % per degree of curve
- NG track: 0.02 % per degree of curve

Degree of curve

A curve is defined by its degree or radius. The degree of a curve is the angle subtended at the center by a chord of 100 feet or 30.48m.

If R is the radius of curve,

Circumference of the curve= $2\pi R$

Angle subtended at the center by the circle = 360°

Angle subtended by the arc of 30.48m = 1750/R

Thus, a 1 degree curve has a radius of 1750 m.

SUPER ELEVATION AND NEGATIVE SUPER ELEVATION

<u>Superelevation on Curves (Cant)</u>

Cant is defined as the difference in height between the inner and outer rails on the curve. It is provided by gradually raising the outer rail above the inner rail level. The inner rail is considered as the reference rail and normally is maintained at its original level. The inner rail is known as the gradient rail.

Function of superelevation

- Neutralizes the effect of lateral force.
- It provides better load distribution on the two rails.
- It reduces wear and tear of rails and rolling stock.
- It provides smooth running of trains and comforts to the passengers.

Equilibrium speed

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

Maximum permissible speed

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

Cant deficiency

Cant deficiency (Cd) occurs when a train travels around a curve at a speed higher than the equilibrium speed. It is the difference between the theoretical cant required for such high speeds and the actual cant provided. As per Indian Railways, Cant deficiency is recommended as follow:

BG Track: 75 mm

MG track: 50 mm

NG track: 40 mm

Cant excess

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

Cant gradient and cant deficiency gradient

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

Rate of change of cant or cant deficiency

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

In the metric system equilibrium superelevation is given by the formula

$$e = \frac{GV^2}{127R}$$

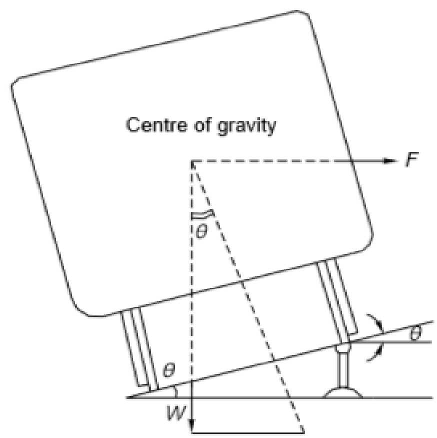
Where,

e is the superelevation in mm,

V is the speed in km/h,

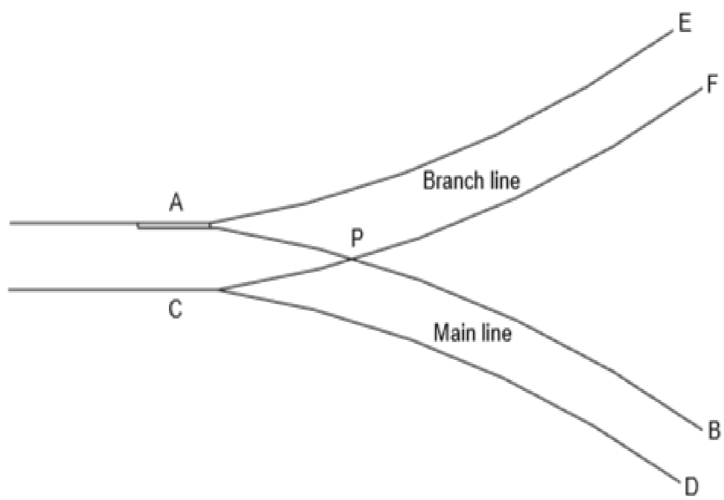
R is the radius of the curve in m, and

G is the dynamic gauge in mm, which is equal to the sum of the gauge and the width of the rail head in mm. This is equal to 1750 mm for BG tracks and 1058 mm for MG tracks.



Negative Superelevation

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



The provision of negative superelevation for the branch line and the reduction in speed over the main line can be calculated as follows.

i. The equilibrium superelevation for the branch line curve is first calculated using the formula

$$e = \frac{GV^2}{127R}$$

ii. The equilibrium superelevation e is reduced by the permissible cant deficiency Cd and the resultant superelevation to be provided is

$$\mathbf{x = e - C_d}$$

where, x is the superelevation, e is the equilibrium superelevation, and C_d is 75 mm for BG and 50 mm for MG. The value of C_d is generally higher than that of e, and, therefore, x is normally negative. The branch line thus has a negative superelevation of x.

iii. The maximum permissible speed on the main line, which has a superelevation of x, is then calculated by adding the allowable cant deficiency ($x + C_d$). The safe speed is also calculated and smaller of the two values is taken as the maximum permissible speed on the main line curve.

SPEED ON CURVES

For all practical purposes safe speed means a speed which protects a carriage from the danger of overturning and derailment and provides a certain margin of safety. Earlier it was calculated empirically by applying Martin's formula:

For BG and MG

Transitioned curves

$$V = 4.4\sqrt{R - 70}$$

Where, V is the speed in km/h and R is the radius in m.

Non-transitioned curves

The Safe speed = four-fifths of the speed calculated using the above equation.

For NG

Transitioned curves

$$V = 3.65\sqrt{R - 6}$$ (Subjected to maximum 50 km/h).

Non-transitioned curves

$$V = 2.92\sqrt{R - 6}$$ (Subjected to maximum 40 km/h).

Indian Railways no longer follows this concept of safe speed on curves or the stipulations given here.

Maximum Permissible speed on curve (Problems included)

Type of curve		*Procedure for calculating max. permissible speed or safe speed*
Fully transitioned curve	(i)	For BG $V = 0.27\sqrt{R(C_a + C_d)}$
	(ii)	For MG $V = 0.347\sqrt{R(C_a + C_d)}$
	(iii)	For NG $V = 3.65\sqrt{R - 6}$ (subject to a maximum of 50 km/h)
Non-transitioned curve with cant on virtual transition	(i)	Cant to be gained over virtual transition is 14.6 m on BG, 13.7 m on MG, and 10.3 m on NG, and the cant gradient is to be calculated accordingly
	(ii)	The cant gradient is not to exceed 1 in 360 (2.8 mm/m) on BG and 1 in 720 (1.4 mm/m) on MG and NG.
Non-transitioned curves with no cant	(i)	Calculate permissible cant deficiency that is to be gained or lost over the virtual transition
	(ii)	The desirable value of rate of change of cant deficiency is 35 mm/sec for BG and 55 mm/sec for MG
Curves with inadequate transition	(i)	Calculate the actual cant or cant deficiency which can be provided taking into consideration its limiting value
	(ii)	The cant or cant deficiency has to be run over the transition length. The rate of change of cant or cant deficiency should not exceed its limiting value. For BG, the desirable value is 35 mm/sec and the maximum permissible value is 55 mm/sec.

Problems:

Example1. Calculate the superelevation and the maximum permissible speed for a 2° BG transitioned curve on a high-speed route with a maximum sanctioned speed of 110 km/h. The speed for calculating the equilibrium superelevation as decided by the chief engineer is 80 km/h and the booked speed of goods trains is 50 km/h.

(i) $R = \frac{1750}{D} = \frac{1750}{2} = 875\,\text{m}$

(ii) Superelevation for equilibrium speed = $\frac{GV^2}{127R}$

where $G = 1750$ mm (c/c distance of 52-kg rail) $V = 80$ km/h and $R = 875$ m.

$$\text{SE} = \frac{1750 \times 80^2}{127 \times 875} = 100.8\text{ mm}$$

(iii) Superelevation for maximum sanctioned speed (110 km/h):

$$\frac{GV^2}{127R} = \frac{1750 \times 110^2}{127 \times 875} = 190.6\text{ mm}$$

Cant deficiency = 190.6 – 100.8 = 89.8 mm

(which is less than 100 mm and hence permissible).

(iv) Superelevation for goods trains with a booked speed of (50 km/h)

$$\frac{GV^2}{127R} = \frac{1750 \times 50^2}{127 \times 875} = 39.4\text{ mm}$$

Cant excess = 100.8 – 39.4 = 61.4 mm (which is less than 75 mm and hence permissible).

(v) Maximum speed potential or safe speed of the curve as per theoretical considerations, being a high-speed route:

$$V = \sqrt{\frac{(C_a + C_d) \times R}{13.76}} = 0.27\sqrt{(C_a + C_d) \times R}$$

where $C_a = 100.8$ mm, $C_d = 89.8$ mm, and $R = 875$ m.

$$V = \sqrt{\frac{(100.8 + 89.8) \times 875}{13.76}} = 110.1\text{ km/h}$$

The maximum permissible speed on the curve is the least of the following:

- **Maximum sanctioned speed, i.e., 110 km/h.**
- **Maximum or safe speed over the curve based on theoretical considerations, i.e., 110.1 km/h.**
- **Also, there is no constraint on speed due to the transition length of the curve.**

Therefore, the maximum permissible speed over the curve is 110 km/h and the superelevation to be provided is 100.8 mm or approx. 100 mm.

SIMPLIFIED METHOD OF CALCULATING PERMISSIBLE CANT AND SPEED

Often a simplified method is used for calculating the permissible cant and the maximum permissible speed in the field. This simplified method is applicable to most cases except those involving very flat curves.

Step 1 Calculate the cant for the maximum sanctioned speed of the section, say, 110 km/h, using the standard formula 2/127 C GV R = . This is C110.

Step 2 Calculate the cant using the same standard formula as for the slowest traffic, i.e., for a goods train which may be running at, say, 50 km/h. This is C50. To this add cant excess. This becomes C50 + Ce.

Step 3 Calculate the cant for equilibrium speed (if decided) using the same standard formula. Let it be 80 km/h. This value is C80.

Step 4 Adopt the lowest of the three values obtained from the preceding steps and that becomes the permissible cant (Ca). The three values are C110, C50 + Ce, and C80.

Step 5 Taking this cant value (Ca), add the cant deficiency and find the maximum permissible speed using the Eqn

Step 1

$$C_{110} = \frac{GV^2}{127R} = \frac{1750 \times 110 \times 110}{127 \times 875} = 190.6\,\text{mm} \qquad \text{(i)}$$

Step 2

$$C_{50} = \frac{GV^2}{127R} = \frac{1750 \times 50 \times 50}{127 \times 875} = 39.4\,\text{mm}$$

On adding cant excess,

$$C_a + C_e = 39.4 + 75 = 114.4 \text{ mm} \qquad \text{(ii)}$$

Step 3

$$C_{80} = \frac{GV^2}{127R} = \frac{1750 \times 80 \times 80}{127 \times 875} = 100.8\,\text{mm} \qquad \text{(iii)}$$

Step 4 The lowest of the three values calculated in the preceding steps is 100.8 mm. Therefore, 100 mm is adopted as the actual cant.

Step 5 Cant to be provided 100 mm, cant deficiency = 75 mm

$$V = 0.27\sqrt{(C_a + C_d) \times R} = 0.27\sqrt{(100 + 75) \times 875}$$
$$= 110.1 = 110 \text{ km/h approx.}$$

Therefore, the maximum cant to be provided 100 mm and the maximum permissible speed is 110 km/h.

Example 2. Calculate the superelevation, maximum permissible speed, and transition length for a 3° curve on a high-speed BG section with a maximum sanctioned speed of 110 km/h. Assume the equilibrium speed to be 80 km/h and the booked speed of the goods train to be 50 km/h.

(i) Radius of curve = $\frac{1750}{D} = \frac{1750}{3} = 583.3$ m

(ii) Equilibrium superelevation for 80 km/h = $\frac{GV^2}{127R} = \frac{1750 \times 80^2}{127 \times 583.3} = 151.2$ mm

(iii) Equilibrium superelevation for maximum sanctioned speed (110 km/h)

$$= \frac{1750 \times 110^2}{127 \times 583.3} = 285.5 \text{ mm}$$

(iv) Cant deficiency = 285.8 mm – 151.2 mm = 134.6 mm
This value of cant deficiency is more than 100 mm (the permitted value of C_d), therefore, take C_d as 100 mm. Now,
Actual cant = 285.8 – 100 = 185.8 mm

However, actual cant is to be limited to 165 mm, and, therefore, this value will be adopted.

(v) Equilibrium superelevation for a goods train with a speed of 50 km/h

$$= \frac{1750 \times 50^2}{127 \times 583.3} = 59 \text{ mm}$$

(vi) Cant excess = actual cant – 59 mm
= 165 – 59 = 106 mm
which is in excess of 75 mm—the permitted value. With 75 mm taken as cant excess, the actual cant to be provided now is 75 + 59 mm = 134 mm. Therefore, a cant of 135 mm should be provided (rounding off to the higher multiple of 5).

(vii) Safe speed or speed potential (for high-speed route)

$$= \frac{\sqrt{(C_a + C_d) \times R}}{13.76} = \frac{\sqrt{(135 + 100) \times 583.3}}{13.76}$$

= 99.6 km/h (or approx. 100 km/h).

(viii) Maximum permissile speed on the curve is the least of the following:
- maximum permissible speed of the section, i.e., 110 km/h
- safe speed on the curve, i.e., 100 km/h

The maximum permissible speed on the curve is, therefore, 100 km/h.

(ix) The length of transition is the maximum value from among the following:

- When taking the rate of change of cant into consideration (35 mm/sec),
  $L = 0.008\ (C_a \times V_m) = 0.008 \times 135 \times 100 \text{ m} = 108 \text{ m}$
- When taking the rate of change of cant deficiency into consideration (35 mm/sec),
  $L = 0.008\ (C_d \times V_m)$
  $= 0.008 \times 100 \times 100 \text{ m}$
  $= 80 \text{ m}$
- When taking the cant gradient into consideration (1 in 720),
  $L = 0.72 \times e = 0.72 \times 135 \text{ m} = 97.2 \text{ m}$

Therefore, the superelevation to be provided is 135 mm, the maximum permissible speed over the curve is 100 km/h, and the length of transition curve is 108 m.

WIDENING OF GAUGE ON CURVES

A vehicle normally assumes the central position on a straight track and the flanges of the wheels stay clear of the rails. The situation, however, changes on a curved track. As soon as the vehicle moves onto a curve, the flange of the outside wheel of the leading axle continues to travel in a straight line till it rubs against the rail. Due to the coning of wheels, the outside wheel travels a longer distance compared to the inner wheel. This, however, becomes impossible for the vehicle as a whole since the rigidity of the wheel base causes the trailing axle to occupy a different position. In an effort to make up for the difference in the distance travelled by the outer wheel and the inner wheel, the inside wheels slip backward and the outer wheels skid forward. A close study of the running of vehicles on curves indicates that the wear of flanges eases the passage of the vehicle round curves, as it has the effect of increasing the gauge. The widening of the gauge on a curve has, in fact, the same effect and tends to decrease the wear and tear on both the wheel and the track.

The widening of the gauge on curves can be calculated using the formula

$$\text{Extra width on curves } (w) = \frac{13(B + L)^2}{R}$$

Where,

B is the wheel base of the vehicle in m,

R is the radius of the curve in m,

$L = 0.02(h^2+Dh)^{1/2}$ is the lap of the flange in m,

h is the depth of flange below top of the rail, and

D is the diameter of the wheel of the vehicle.

Example The wheel base of a vehicle moving on a BG track is 6 m. The diameter of the wheels is 1524 mm and the flanges project 32 mm below the top of the rail. Determine the extra width of the gauge required if the radius of the curve is 168 m. Also indicate the extra width of gauge actually provided as per Indian Railways standards.

Solution

(i) Lap of flange $L = 0.02\sqrt{h^2 + Dh}$

where $h = 3.2$ cm is the depth of the flange below the top of the rail and $D = 152.4$ cm is the diameter of the wheel. Therefore,

$$L = 0.02\sqrt{h^2 + Dh}$$

$$= 0.02\sqrt{3.2^2 + (152.4 \times 3.2)} = 0.446\,\text{m}$$

(ii) Extra width of gauge $(w) = \dfrac{13(B + L)^2}{R}$

$$= \frac{13(6 + 0.446)^2}{168} = 3.21\,\text{cm} = 32.1\text{ mm}$$

(iii) As per Indian Railways standards, an extra width of 5 mm is provided for curves with a radius less than 400 m in actual practice.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – II – Railways, Airport and Harbour Engineering – SCIA1701

II. Railway Construction and Maintenance

Track construction - Calculation of Materials required for track laying - Track maintenance - Track drainage - Types of stations: Way side, Junction, Terminal - Types of station yards: Passenger, Goods, Marshalling and Locomotive - Station equipments - Introduction to Modern Developments in Railways

TRACK CONSTRUCTION

Steps involved in Track Construction

Step 1: Earthwork – Formation and Consolidation

Step 2: Plate Laying

Step 3: Laying of Ballast

Step 1: Earthwork – Formation and Consolidation

Formation – Depending upon the rail level and general contour of the area, the formation may be laid in an embankment or in a cutting. A formation laid in an embankment is normally preferred because it affords good drainage. The height of the embankment also depends on the high flood level (HFL) of the area and a reasonable free board should be given above the HFL.

Consolidation – the primary consolidation results from the expulsion or extrusion of water from the voids in fine-grained soil Causes settlement in structures and embankments over a period of time. The methods of accelerating consolidation include placing a surcharge and/or installing sand columns or wick drains can be done. Secondary consolidation is the rearrangement of cohesive soil grains and to pack the track so that the larger quantities of stone ballast are not lost by sinking into loose earth formation.

Step 2: Plate Laying - Laying the Rails and Sleepers over the ready formation.

There are three distinct methods of construction of railway track. These are:

1. Telescopic Method
2. Tramline Method
3. American / Mechanical Method

1. **Telescopic Method of Construction of Railway Track**
   - In this method, rails, sleepers and fastenings are unloaded from the material train as close to the rail head as possible. The sleepers are carried by carts or men along the adjoining service road and spread on the ballast. The rails are then carried on pairs to the end of last pair of connected rails and linked.
   - To carry rails manually over a long distance is a tedious job. So certain carriers called Anderson rail. Carriers are used to carry rails to the ends of the rail head.
   - It can also take rails up to a head last pair linked with the help of temporary track consisting of 3" x 3" angle irons of the same length as rails and fastened to the sleepers.
   - A further consignment of the material is deposited at the advances rails head and the procedure is repeated.
2. **Tramline Method Railway Track Construction**
   - This method is used where tram carrier are installed for carrying earthwork or in rainy season due to difficulty in movement of cart. Some tramline is established on with a gauge of 2'-2'-6". The basic difference between this and telescopic method lies in the conveyance and spreading of the sleepers.
   - The track can be assembled at more than one point simultaneously, which is the great advantage of this method. Sometimes an additional track is laid on the side of existing track for which this method is best.

3. **Mechanical Method Railway Track Construction**

This method is extensively used in Britain and America by using special track laying machine. There are two types of machines available. In first type of machine, the track material carried by the material. Train is delivered at the rail head and laid in the required position by means of projecting arm or mounted on the truck nearest to the rail head. The material train moves forward on the assembled track and operation is repeated.

In the second type of machines a long cantilevered arm projecting beyond. The wagon on which is fitted. A panel of assembled track consists of pair of rail with appropriate number of sleepers on the ballast layer. This panel is conveyed by special trolley running over the wagons of material train to the jibs. It is lowered by the jib in the required position and connected to the previous panel. The track laying machine then movies forwarded and operation is repeated.

Step 3: Laying of Ballast

Ballast trains also run on the section and unload the ballast on the track, which is then packed manually with the help of beaters.


CALCULATION OF MATERIALS REQUIRED FOR TRACK LAYING

Requirement of Track Material for BG Track

Rails

The standard length of the rails is 13 m for BG and 12 m for MG lines.

$$\text{No. of rails per km for BG lines} = \frac{1000}{13} \times 2$$
$$= 77 \times 2 = 154$$

$$\text{Wt of 52-kg rails per km} = 52 \times 154$$
$$= 8008 \text{ kg}$$

Number of sleepers

The number of sleepers to be used depends upon the sleeper density. Assume sleeper density to be $M + 7$, where M is the length of the rail in metres.

Number of sleepers per rail = 13 + 7 = 20

Number of sleepers per km = 77 × 20 = 1540

Fittings and fastenings

(a) No. of fish plates per km = 2 × number of rails per km
= 2 × 154 = 308

(b) No. of fish bolts = 4 × number of rails per km
= 4 × 154 = 616

(c) No. of bearing plates = number of sleepers × 2
= 1540 × 2 = 3080

(iv) Number of dog spikes = number of sleepers × 4
= 1540 × 4 = 6160

The requirement of track materials for MG lines can also be calculated in the same manner.

TRACK MAINTENANCE

Track maintenance becomes a ***necessity*** due to following reasons.

- Due to the constant movement of heavy and high-speed trains, the packing under the sleepers becomes loose and track geometry gets disturbed. The gauge, alignment, and longitudinal as well as cross levels of the track thus get affected adversely and the safety of the track is jeopardized.
- Due to the vibrations and impact of high-speed trains, the fittings of the track come undone and there is heavy wear and tear of the track and its components.
- The track and its components get worn out as a result of the weathering effect of rain, sun, and sand.

The ***advantages*** of track maintenance are as follows.

- If the track is suitably maintained, the life of the track as well as that of the rolling stock increases since there is lesser wear and tear of their components.
- Regular track maintenance helps in reducing operating costs and fuel consumption.
- Small maintenance jobs done at the appropriate time such as tightening a bolt or key, hammering the dog spike, etc., helps in avoiding loss of the concerned fitting and thus saving on the associated expenditure.
- When track maintenance is neglected for a long time, it may render the track beyond repair, calling for heavy track renewals that entail huge expenses.

The following ***characteristics*** are required of track maintenance,

- The gauge should be correct or within the specified limits
- There should be no difference in cross levels except on curves, where cross levels vary in order to provide superelevation
- Longitudinal levels should be uniform
- The alignment should be straight and kink-free
- The ballast should be adequate and the sleepers should be well packed.
- There should be no excessive wear and tear of the track and all its components and fittings should be complete.
- Track drainage should be good and the formation should be well maintained.

The **daily maintenance** consists of

- General inspection of the track
- Checking up of all fastenings and fittings
- Tightening of bolts wherever required
- Reporting by unusual occurrence

The **periodic maintenance** consists of detailed inspection of the track to detect defects in the track which may not be detected during daily maintenance. They are listed below:

1. Surface of Rails

   Operations involved are;

- Packing the ballast
    - i. Through Packing
    - ii. Scissor Packing

iii. Shovel Packing

- Surfacing the track
- Boxing and Dressing
- Leveling
- Lifting
- Surface defects and remedies
    i. High Joint / Riding Joint
    ii. Blowing Joint
    iii. Pumping Joint
    iv. Buckling of Track
    v. Centre Bound Track
    vi. Hogged Rails
    vii. Corrugated or Roaring Rails
- Spot packing and track lifting

2. Track Alignment
    - Realignment of Straight Tracks
    - Realignment of Curved Tracks
3. Gauge
4. Proper Drainage
    - Cleaning the ballast
    - Cleaning of cess
    - Surface Drainage
    - Underground Drainage
5. Track Components
    - Maintenance and renewal of rails
    - Maintenance and renewal of Sleepers – Spot Renewal and Through Renewal
    - Maintenance and renewal of fittings
6. Bridge and its approaches
    - Maintenance of foundations
    - Maintenance of Substructure and protection works
    - Maintenance of superstructure
    - Maintenance of Track on bridge and its approaches
7. Rolling Stock
    - Maintenance of Locomotives
    - Maintenance of Passenger Coaches
    - Maintenance of Goods wagons
8. Points and Crossings
9. Level Crossings
10. Tunnels

Maintenance of track materials

- The top surface of the rails should be kept at the same level
- Ballast under sleepers should be regularly packed

- Defective sleepers should be replaced immediately
- Worn-out rails should be replaced
- Kink or fracture rails should be replaced
- Fastening should be tightened and oiled
- Gauge should be checked and corrected
- Ensure that both the rails are at same level
- Maintain track drainage properly
- Oiling and greasing of fishplates regularly
- Flanges and check rails should be kept free from dust

Maintenance of bridges

- Proper embankment should be provided near the bridge
- Avoid scouring near abutments and piers
- Flood control measures should be taken near the bridges
- Riveted joints should be inspected periodically
- Bed blocks should be checked regularly
- Steel bridges should be painted regularly
- Bearings of the girders should be oiled regularly
- Masonry works should be inspected regularly

Maintenance of rolling stock

- Lubrication of all reciprocating parts and bearings
- Worn out parts should be replaced the rolling stock
- It is necessary to clean the different parts every day
- All axles which have run 3,22,000 Km should be replaced
- A passenger vehicle used for 30years should be dismantled and re-assembled
- The locomotive boilers have to be carefully maintained and removed every 15 years

High Joint / Riding Joint

High joints result in a very uncomfortable ride on the track. High joints are the outcome of the following.

- Changes in track structure, e.g., provision of wooden sleepers in a track that is normally laid with metal sleepers. Since it is easier to maintain wooden sleepers as compared to metal sleepers, this discrepancy in the type of sleepers results in high joints, which in turn produces the effect of camel back riding.
- Sinking of intermediate sleepers
- Over packing of joint sleepers.

This defect is removed by lifting and packing the intermediate sleepers.

Blowing Joint and Pumping Joint

A joint is called a ***blowing joint*** when it blows out fine dust during the passage of a train. The surroundings of such a joint are always coated with fine dust. A blowing joint becomes a ***pumping joint*** during the rainy season when it pumps out mud and water from the mud pockets formed below the joint. This defect is caused because of poor maintenance of the joint, particularly of the packing of the joint sleepers, unclean ballast, and bad drainage, and also sometimes due to surface defects in the rail such as scabbing. As moving loads pass over the joint, the joint sleepers get depressed and lifted up constantly. As this happens, the dust or mud gets sucked up and spreads in the vicinity of the joint. The remedy lies in

- deep screening the ballast below the joint and shoulder sleepers,
- packing the joint sleeper and shoulder sleepers thoroughly,
- providing proper drainage at the joint,
- tightening loose fittings, and
- Adjusting the creep, if any.

Buckling of Track

A rail track is liable to get distorted, particularly in hot weather when the compressive forces in the track exceed the lateral or longitudinal resistance of the track. The buckling of the track is a matter of grave concern as it may lead to derailments and even serious accidents.

A track can buckle due to the following reasons.

- Inadequate resistance to track due to deficiencies in the ballast
- Ineffective or missing fastenings
- Laying, destressing, maintaining, or raising the track outside the specified rail temperature range, especially is hot weather
- Excessive creep, jammed joints, sunken portions in a welded track


Centre Bound Track

This defect is generally noticed in wooden and steel trough sleeper tracks. This defect occurs when, as a consequence of plying traffic, the sleeper starts to receive support at the centre instead of at the ends. If proper care in not taken during through packing and the middle portion of the sleeper is also packed, the defect can develop very early. Even under normal circumstances, the ballast under the sleeper ends, where the sleeper rests, gets more depressed compared to the ballast at the centre because of the impact of the moving loads and in the process the sleeper, instead of resting at the ends, stats to rest at the centre.

Centre binding of the sleepers leads to the rocking of the trains and is detrimental to the quality of the track. The defect can be removed by loosening the ballast at the centre of the sleeper. It is considered a good practice to make a small recess or depression in the ballast section at the centre of the sleeper.


Hogged Rails

Rail ends get hogged due to poor maintenance of the rail joint, yielding formation, loose and faulty fastenings, and other such reasons. Hogging of rails causes the quality of the track to deteriorate. This defect can be remedied by measured shovel packing.


Corrugated or Roaring Rails

The corrugation of rails is quite an undesirable feature. When vehicles pass over corrugated rails, a roaring sound is produced, possibly due to the locking of air in the corrugation. This phenomenon is sometimes called ‘Roaring of rails’. This unpleasant and excessive noise causes great inconvenience to the passengers.

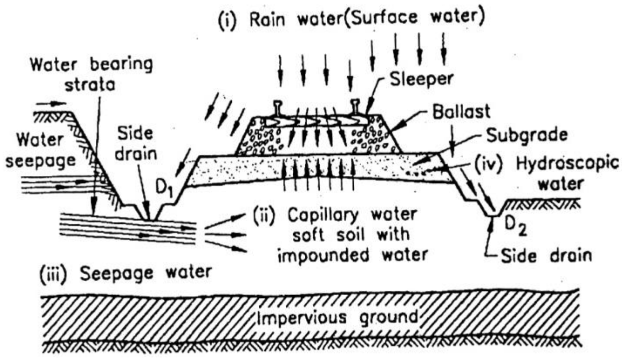
Corrugation also results in the rapid oscillation of rails, which in turn loosens the keys, causes excessive wear to fittings, and disturbs the packing. Corrugation can be removed by grinding the rail head by a fraction of a millimeter. No method has been standardized on Indian Railways to grind rail surfaces


TRACK DRAINAGE

Track drainage can be defined as the interception, collection and disposal of water from, upon or under the track. It is accomplished by installing a proper surface drainage and sub-surface drainage system.

Sources of water in a Railway Track:

1. Surface water due to rain, dew, snow.
2. Seepage water from adjacent area.
3. Moisture sucked up by capillary action resulting in increase of moisture in the subgrade or embankment.
4. Hygroscopic water or held water
5. Rain water surface



A good track drainage system should essentially ensure that no water percolates into the track at either the surface or the sub-surface levels.

The efficiency of a modern track depends upon the strength and stability of the formation which in turn depends upon the good track drainage.

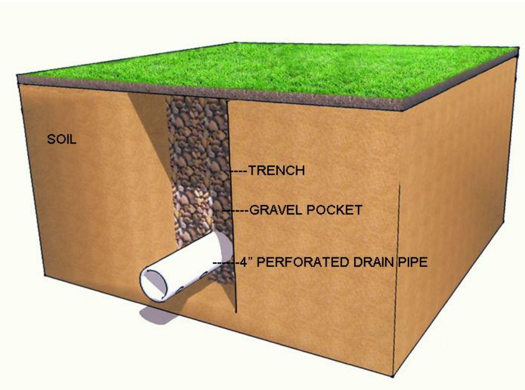
Track drainage should be handled in two distinctive phases

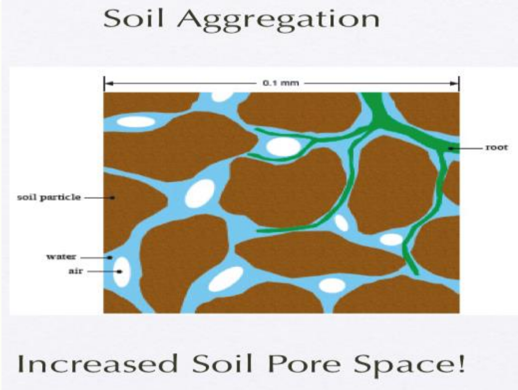
1. Surface drainage
2. Sub-surface drainage

Surface drainage

Surface water due to rain, snow or from adjacent areas should be drained off properly by designing well-planned and effective surface drains. For bank and formation, good quality soil having well graded particles and high internal friction should be used. The soil should not swell or shrink with variation in moisture content. The surface water is first collected in well designed side drains and cross-drains which are further disposed off at the nearest stream or natural water course. Cross drainage structures like culverts and bridges may be necessary for disposing of the surface water.

Sub-surface drainage



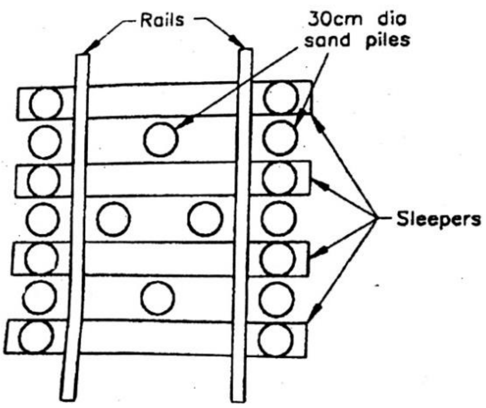


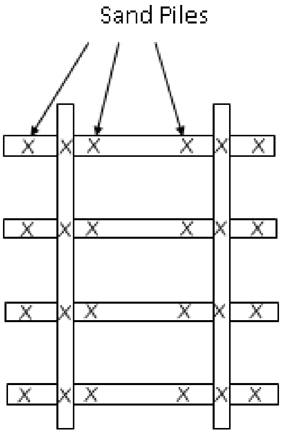
Sand piles

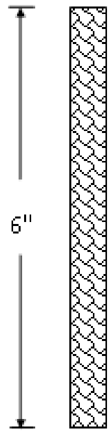
Sand drains may be used for the removal of surface water from the embankment. In this method, holes of 30 cm diameter and 1.8 to 3.0 m deep are made between two rails and on the sides of the rails in the embankment. These holes are filled with coarse sand thus forming sand piles.

Functions of sand piles are

- To support the track.
- Sand piles compact the soil and provide mechanical support to the subgrade just like wooden piles.
- The drainage of the subgrade also improves, as water rises to the surface through the sand piles by capillary action and evaporates.

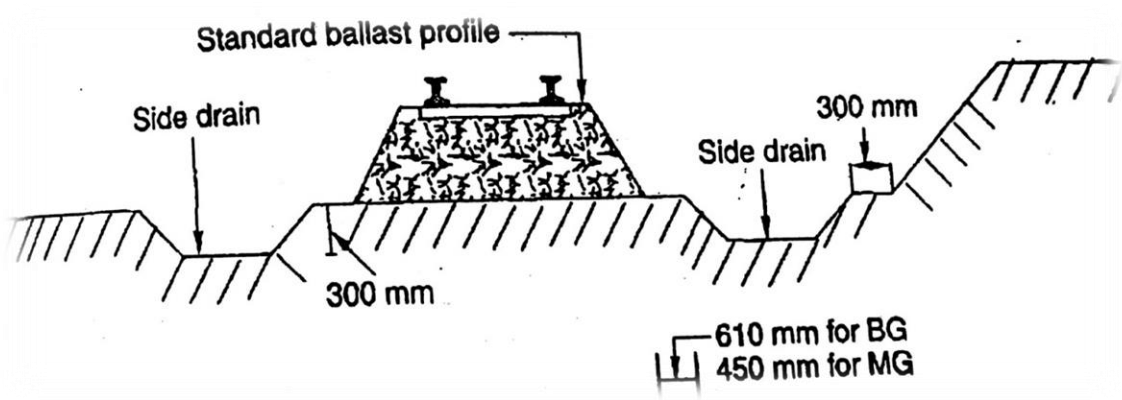






Side drains

- Side drains should be provided along the track cutting and zero fill locations, where in the cess level is not above the ground level.
- The figure shows the typical cross section of a side drain. Side drain must have an adequate gradient and cross section to enable the free flow of collected water.
- All side drains should be provided with concrete lining.



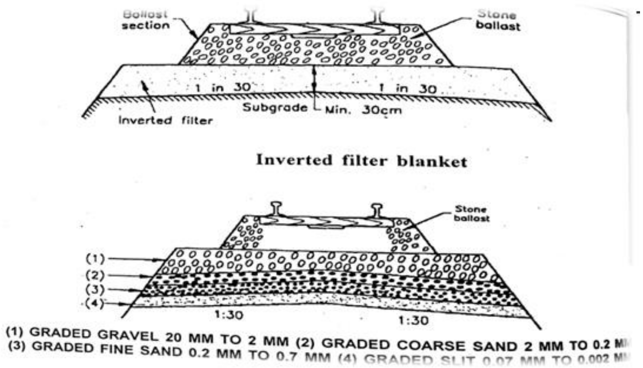
The variations in moisture content of subgrade or embankment are mainly caused due to:

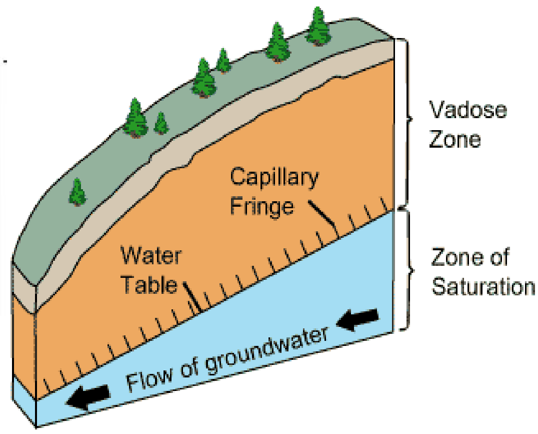
- Fluctuations in movement of capillary water
- Seepage water from adjacent area
- Rising of ground water table
- Percolation of rain water

The object of sub-surface drainage is to keep these fluctuations of moisture as minimum as possible.

<u>Drainage of capillary water</u>

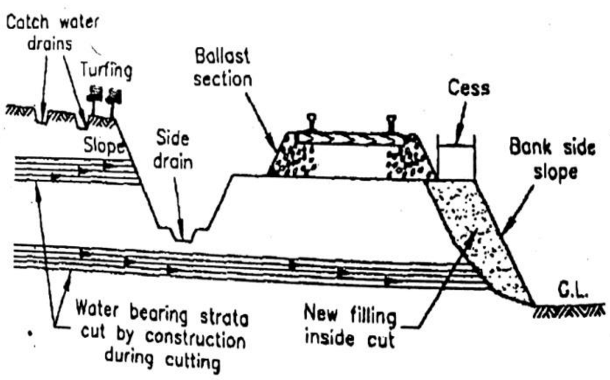
The capillary rise in the embankment can be prevented by the ballast as shown in the embankment or inverted filter of pervious material below the ballast

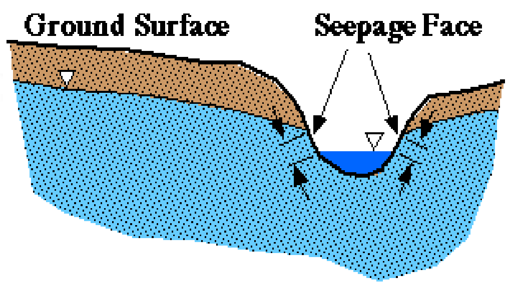




<u>Drainage of seepage water</u>

In case of track in cuttings, the water seeps from adjacent area to sub The surface water entering the subgrade is prevented by providing catch water drains at the cutting and side drains.

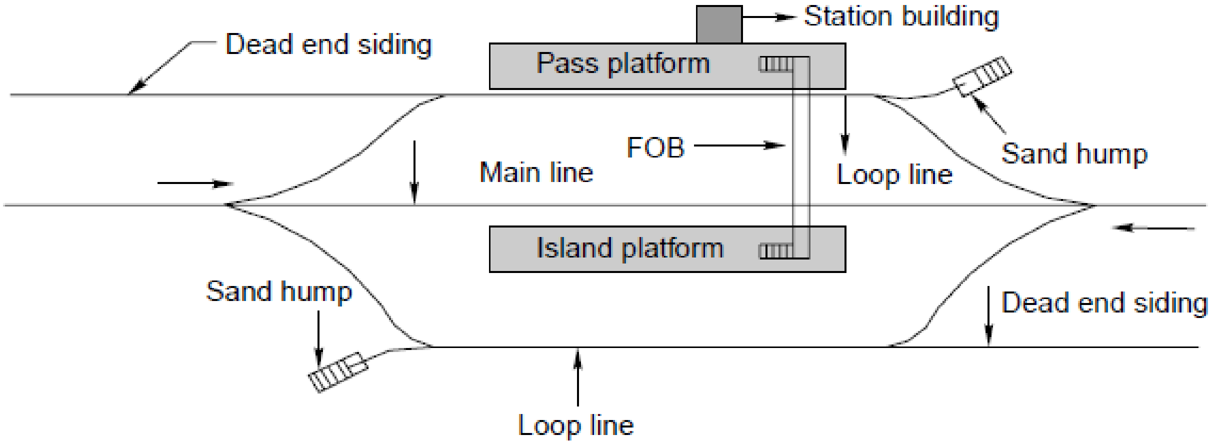




TYPES OF STATIONS

WAY SIDE – A wayside station has arrangements for controlling the movement of trains on block sections. The idea of a wayside station was initially conceived for single line sections, to facilitate the crossing of trains going in opposite directions so that there may be a more rapid movement of trains. Three types of wayside stations are:

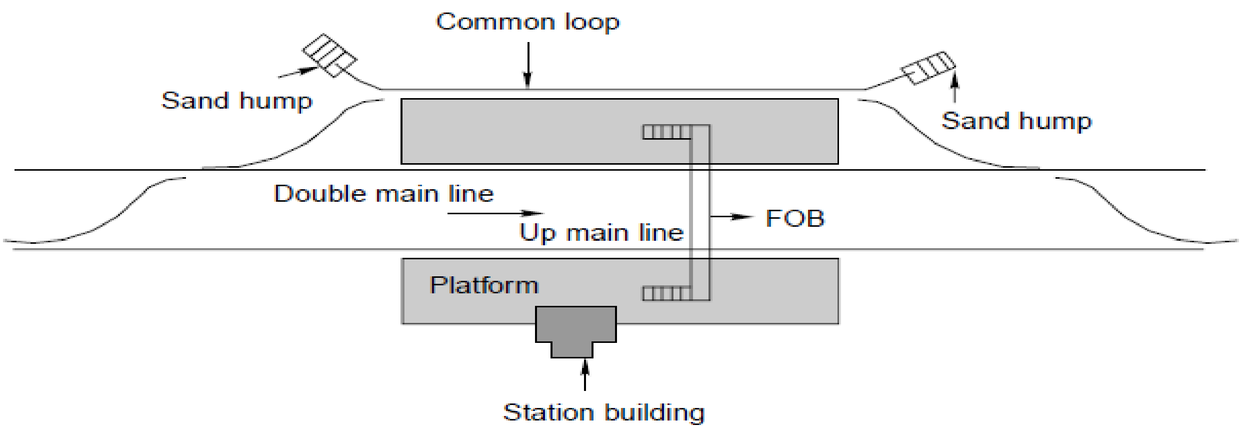
1. **Wayside or crossing station on a single-line section -** Increasing traffic on a single line section necessitates the construction of a three-line station, which provides an additional line as well as more facilities for passing traffic. A typical layout of a three line station providing one additional line and simultaneous reception facilities is given in Figure. It may be possible to improve the facilities further by introducing an additional line to deal with goods traffic. The following are some of the important features of this track layout.



A wayside or crossing station on a single-line section

   a) It is a three-line station and provides facilities for the simultaneous reception of trains from both sides because of the proximity of sand humps in each direction.
   b) There are two platforms, namely, an island platform and a platform near the station building. The island platform can deal with two stopping trains simultaneously. Also, if a goods train has to be stopped at an island station, it can be accommodated on the loop line of the platform, thus keeping the main line free for run-through traffic. Important trains can be made to halt on the platform near the station building.
   c) There is a dead end siding at either end of the station to accommodate wagons that are marked sick.
   d) The foot over bridge (FOB) helps the passengers to reach the island platform from the station building and vice versa.

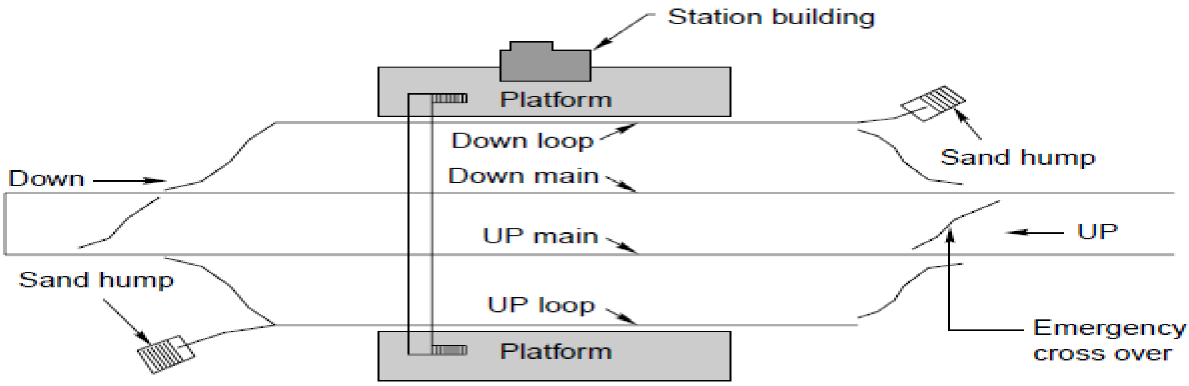
2. **Double-line crossing station with an extra loop -** In the case of a double-line section, which consists of separate up and down lines to deal with traffic moving in either direction, the layout of a station yard is somewhat different. The figure below shows a double-line station with three lines receiving, with one common loop for trains coming from both sides. Some of the important features of this layout are as follows.



Double-line crossing station with three lines

a) This is a wayside station for a double-line section with almost minimum facilities.
b) In addition to two main lines an up line and a down line, there is a common loop that can receive trains from either direction. There is a total of three lines only.
c) It consists of two platforms, one an island platform and the other a platform beside the station building.
d) There is a foot over bridge to connect the station building to the island platform and back.
e) There are emergency crossovers provided on either side of the station so that it can be converted into a single-line station in the case of an emergency

3. **Double-line crossing station with four lines -** The more common layout of a station yard on a double-line section has four lines station as shown. The important features of this layout are as follows.



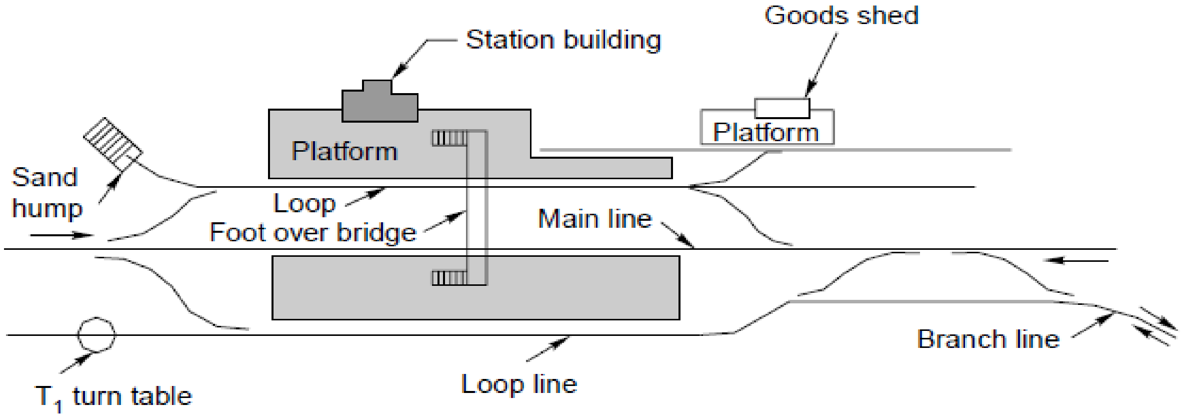
Double-line crossing station with four lines

a) This is a four-line station, where, apart from two up and down main lines, there are two extra loops. These loops are directional loops, i.e., one is known as a down loop as it is meant for down trains while the other is an up loop and is meant for up trains.
b) There are two platforms provided with connection loops. One of these platforms can also be an island platform.
c) There is provision of a foot over bridge to connect the two platforms.
d) Two emergency crossovers are provided on either side of the station so that is can be converted into a single-line station in the case of an emergency.

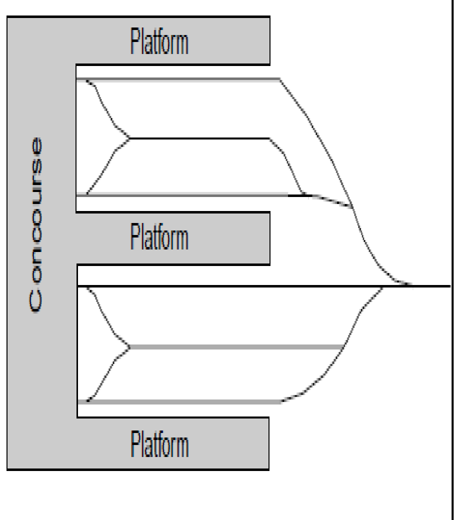
JUNCTION **-** A junction station is the meeting point of three or more lines emerging from different directions. Normally at junctions, trains arrive on branch lines and return to the same station from where they started or proceed to other stations from where they again return to their originating stations.

The important features of junction stations are as follows.

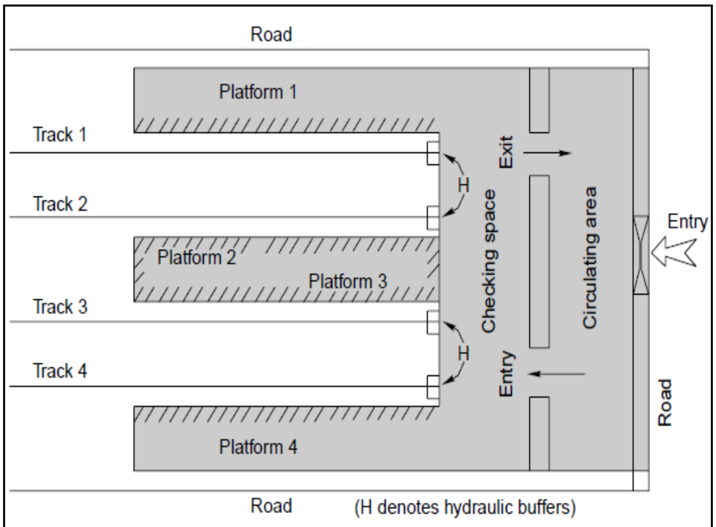
- There are two platforms—one is the main line platform and the other is an island platform. In case the timings of two trains match, both the trains can be received and made to wait on either side of the island platform. This helps in the easy trans-shipment of passengers and luggage. Also, main line as well as branch line trains can be received on the main platform.
- A foot over bridge is provided for passengers to move between the station platform and the island platform.
- It is provided with a small goods siding and a goods platform to deal with goods traffic.
- A turntable is provided for reversing the direction of an engine, if required.
- The emergency crossover on provided either side of the station helps in switching to a single-line set-up in the case of an emergency.



TERMINAL **-** The station at which a railway line or one of its branches terminates is known as a terminal station or a terminal junction. The reception line terminates in a dead end and there is provision for the engine of an incoming train to turn around and move from the front to the rear of the train at such a station. In addition, a terminal station may need to be equipped with facilities for watering, cleaning, coaling, fuelling, and stabling the engines; storing, inspecting, washing and charging the carriages; and such other works.



Terminal station with run round line



Layout of a big terminal station

TYPES OF STATION YARDS

A yard is a system of tracks laid out to deal with the passenger as well as goods traffic being handled by the railways. This includes receipt and dispatch of trains apart from stabling, sorting, marshalling, and other such functions. Yards are normally classified into the following categories.

Passenger - The main function of a coaching yard is to deal with the reception and dispatch of passenger trains. Depending upon the volume of traffic, this yard provides facilities such as watering and fuelling of engines, washing of rakes, examination of coaches, charging of batteries, and trans-shipment of passengers.

Goods - A goods yard provides facilities for the reception, stabling, loading, unloading, and dispatch of goods wagons. Most goods yards deal with a full train load of wagons. No sorting, marshalling, and reforming is done at goods yards except in the case of 'sick' wagons or a few wagons booked for that particular station. Separate goods sidings are provided with the platforms for the loading and unloading of the goods being handled at that station.

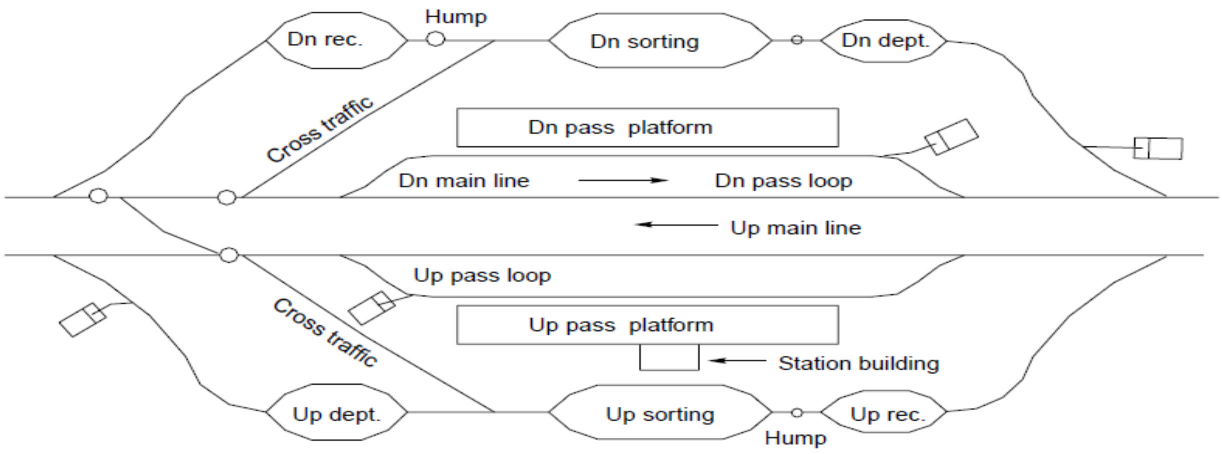
Marshalling - A goods yard which deals with the sorting of goods wagons to form new goods trains is called a marshalling yard. This yard receives loaded as well as empty goods wagons from different stations for further booking to different destinations. These wagons are separated, sorted out, properly marshaled, and finally dispatched bearing full trainloads to various destinations. The marshalling of trains is so done that the wagons can be conveniently detached without much shunting en route at wayside stations.

Functions - A marshalling yard serves the following functions at the specified locations within the yard itself.

Reception of trains - Trains are received in the reception yards with the help of various lines.

Sorting of trains - Trains are normally sorted with the help of a hump with a shunting neck and sorting sidings.

Departure of trains - Trains depart from departure yards where various lines are provided for this very purpose. Separate yards may be provided to deal with up and down traffic as well as through trains, which need not be sorted out.



Marshalling yard with separate humps and separate sorting lines

Marshalling yards can be classified into three main categories, namely, flat yards, gravitation yards, and hump yards. This classification is based on the method of shunting used in the marshalling yard.

Flat yard - In this type of yard, all the tracks are laid almost level and the wagons are relocated for sorting, etc., with the help of an engine. This method is costly, as it involves frequent shunting, which requires the constant use of locomotive power.

The time required is also more as the engine has to traverse the same distance twice, first to carry the wagons to the place where they are to be sorted and then to return idle to the yard. This arrangement, therefore, is adopted when

a) There is limitation of space,
b) There is a severe limitation of funds, or
c) The number of wagons dealt with by the marshalling yard is very low.

Gravitation yard - In this yard, the level of the natural ground is such that it is possible to lay some tracks at a gradient. The tracks are so laid that the wagons move to the siding assigned for the purpose of sorting by the action of gravity. Sometimes, shunting is done with the help of gravity assisted by engine power. However, it is very seldom that natural ground levels are so well suited for gravitation yards.

Hump yard - In this yard, an artificial hump is created by means of proper earthwork. The wagons are pushed up to the summit of the hump with the help of an engine from where they slide down and reach the sidings under the effect of gravity. A hump yard, therefore, can be said to be a gravitation yard as shunting is done under the effect of gravity.

Locomotive - This is the yard which houses the locomotive. Facilities for watering, fuelling, examining locomotives, repairing, etc., are provided in this yard. The yard layout is designed depending upon the number of locomotives required to be housed in the locomotive shed. The facilities are so arranged that a requisite number of locomotives are serviced simultaneously and are readily available for hauling the trains. Such yards should have adequate space for storing fuel. The water supply should be adequate for washing the locomotives and servicing them.

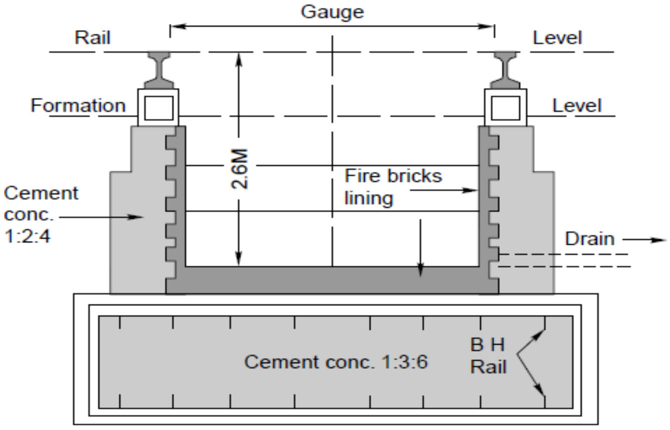
STATION EQUIPMENTS

A lot of equipment is required at railway stations and yards for the efficient working of the railway system. This equipment serves the following purposes.

- Providing facilities for the convenience of passengers—platforms, foot over bridges, and subways.
- Receipt and dispatch of goods traffic—cranes, weigh bridges, loading gauges, and end loading ramps.
- Equipment for locomotives and coaches—locomotive sheds, examination pits, ash pits, water columns, turntables, and triangles.
- Isolation of running lines—and derailing switch, scotch block, sand humps, buffer stops, and fouling marks.

Ash pits

Ash pits (also called de-ashing Pits) are provided to collect the ashes falling from the locomotives. They are rectangular in shape and of a depth of about 1 m and are lined with fire bricks. The length of the ash pits should be adequate so that the longest locomotive can be de-ashed on the pit. The length is normally 15.9 m for BG locomotives. The ash pits are suitably sloped from the centre towards the ends so that water can be drained effectively.



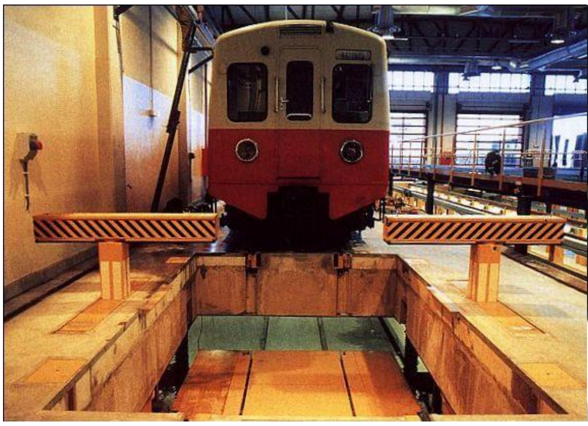
The ash pits should be cleaned as often as possible. The ashes should first be dumped outside the pit and subsequently removed and stored at a suitable place for further disposal. The area around the ash pit should be paved and ample space should be provided for the picking up and storage of cinder. Ash pits are normally provided at those points in the locomotive sheds where the locomotives turn for cleaning or dropping of fire. These are also provided in big stations at places where the locomotives collect water for de-ashing.

Examination Pits

Examination pits (also called outgoing pits) are used both for fire de-ashing before the locomotives leave the sheds and for outgoing engine examination and repairs. These pits should have a minimum length of 25 m with stairs at the ends to enable the staff to go underneath the locomotives for inspection and repair. The pit should be about 1 m deep and lined with fire bricks for about 6 m in the centre where fire cleaning is to be carried out. A water column should be provided by the side of each pit.

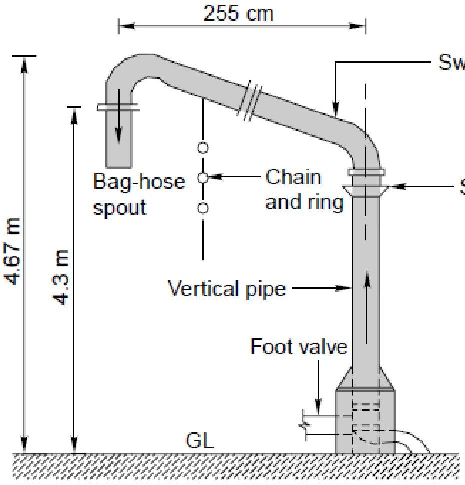
Drop Pits

Drop pits are provided in order to enable the wheels of the locomotives to be removed for examination, repairs, and renewals. These pits are normally provided at right angles to the track. Mobile jacks are installed to enable the wheels and axles to be removed.




Water Columns

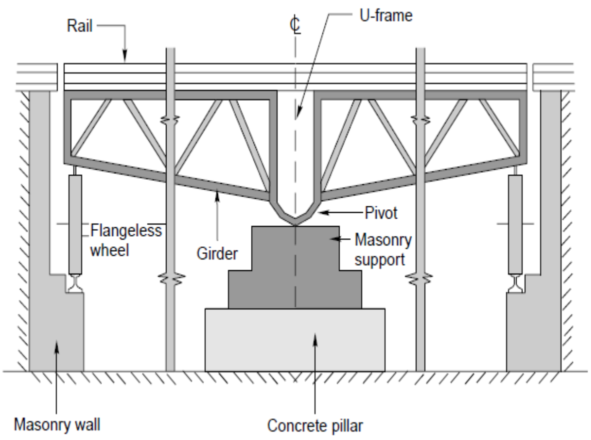
Water columns are provided to supply water to the locomotives. A water column consists of a vertical pipe with a shrivel arm of either a horizontal shape or the shape of a swan’s neck. A bay hose spout is provided at the end of the arm to enable water to be diverted to the opening in the engine tender. A foot valve is fixed inside the water column and water is made available from a suitably located high service tank.



Water columns are provided in locomotive yards as well as at various stations, where engines are required to be watered and fuelled.

Turntable

A turntable is a device used for changing the direction of a locomotive. It is normally provided at terminal stations, locomotive yards, and marshalling yards.



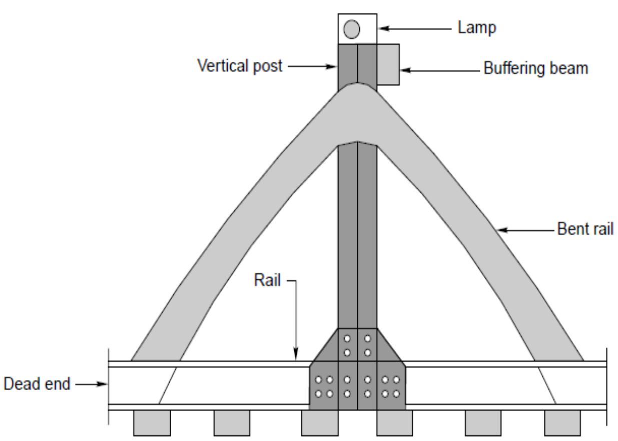
Triangles

Triangles are used for reversing the direction of engines at locations where providing a costly turntable may not be justified and where the available area is adequate for the provision of a triangle. Triangles are normally provided at the terminals of short lines.

Buffer Stop

Buffer stops or ‘snag dead ends’ are provided at the end of a siding to ensure that the vehicles stop while still on the track and do not go off it. The buffer stop is a type of barrier placed across the track which stops the vehicles from going beyond the selected point. It’s essential features are the following.

- The buffer stop should be structurally strong to take the impact of a rolling vehicle.
- It should have a buffer disc with a cross-sleeper, which is normally painted red. A red lamp should be provided at its centre for night indication.
- Normally the track should be straight for some distance near the buffer stop.
- It should be visible from a long distance.



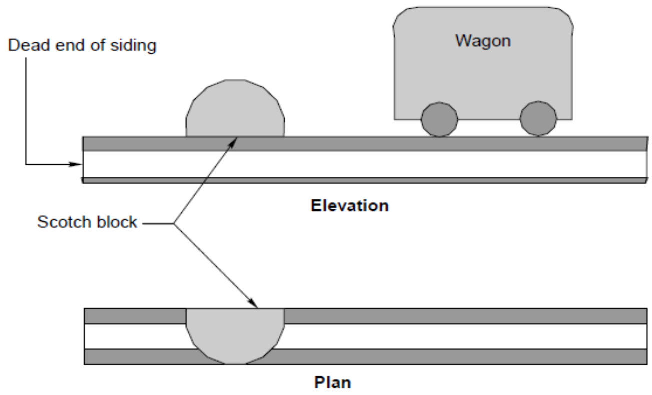


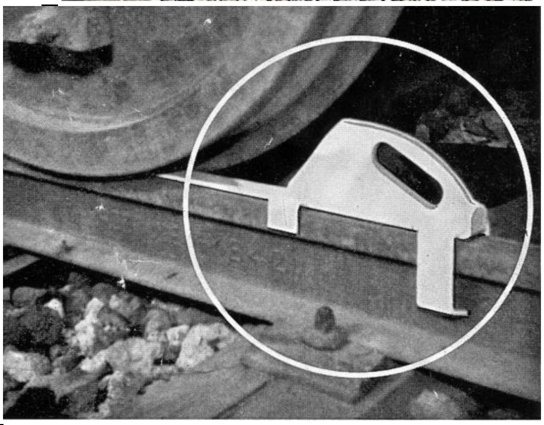
Scotch Block, Derailing Switch, and Sand Hump

It is normal practice to isolate a through running line from a siding so that a vehicle standing on the siding does not accidentally roll onto the running line and foul the same. A scotch block or derailing switch is provided on a siding or shunting neck to ensure that the vehicle does not go beyond a particular point and that if this happens, the vehicle gets derailed.

Scotch block

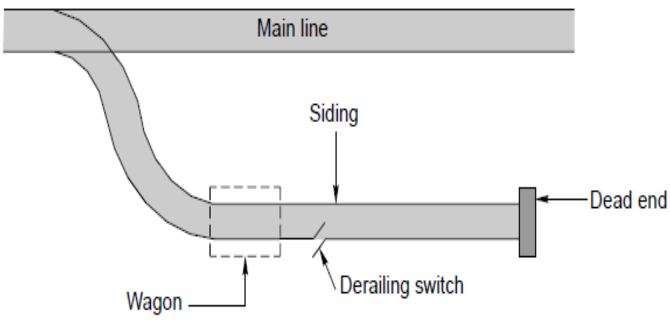
A scotch block is a wooden block placed on the rail and properly held in its place with the help of a device to form an obstruction. Once it is clamped in position, the scotch block does not allow a vehicle to move beyond it.





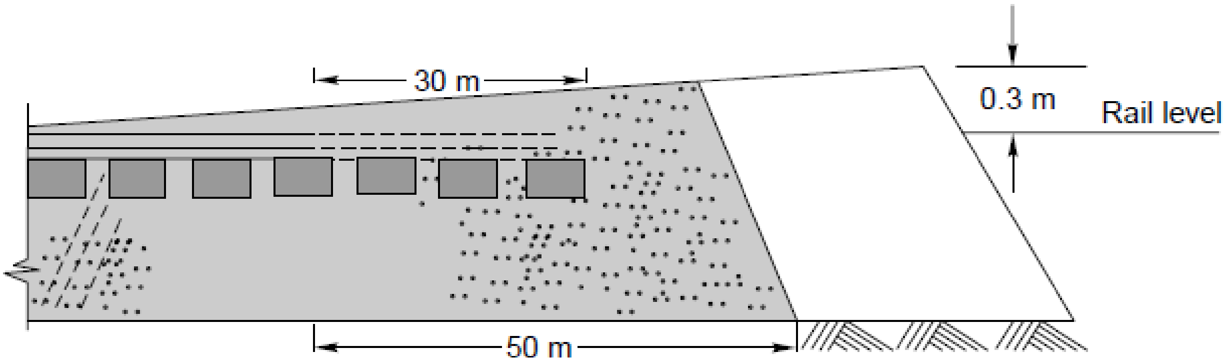
Derailing switch

A derailing switch consists of a half-switch, i.e., only a tongue rail, which in its open position faces away from the stock rail, leaving a gap in between, and this causes a discontinuity in the track. A vehicle cannot go beyond this point and gets automatically derailed if it does manage to do so. The switch can be closed with the help of a lever and a vehicle can then traverse it normally. This is also called a *trap switch*.



Sand hump

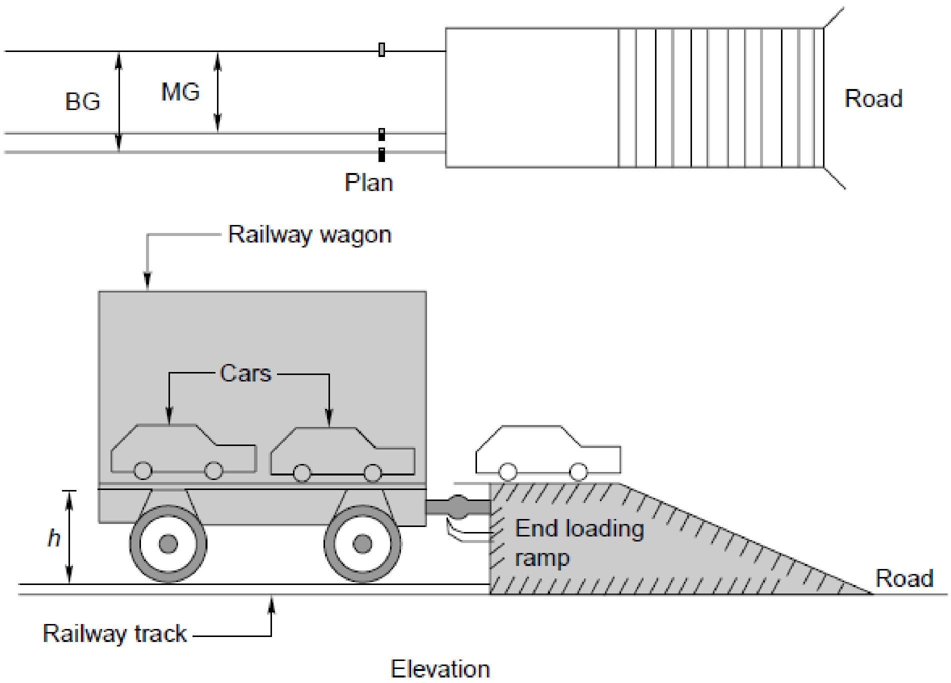
This is possibly the most improved method of isolating and stopping a moving vehicle without causing much damage to it. The sand hump is normally provided on the loop line with the idea that in case an incoming train overshoots when being received on the loop line, the sand hump can make it stop while ensuring that there is least damage to it.



A sand hump consists of a mound of sand of a specified cross section that covers the track under the end of a dead end siding, which is laid on a rising gradient. A moving vehicle comes to a stop because of the combined resistance of the sand hump and the rising gradient.

End Loading Ramps

End loading ramps are provided to allow the unloading of the wagons at their rear end. Such ramps are also used for unloading cars and other mobile vehicles. An end loading ramp has the following essential features.



It has a dead end siding with a buffer stop and a platform with a ramp. The platform is at a height of 1.3 m for BG and 0.86 m for MG lines. A small gap is maintained between the buffer stop and the ramp platform to minimize the damage to the platform. This gap is covered by the hinged plates of the wagon while it is being unloaded.

Cranes

Cranes are normally provided in goods sheds to load and unload bulky or heavy material such as heavy machines and logs from wagons. These are normally of three types.

Fixed jib crane This crane is fixed at a convenient location on the goods platform for the purpose of loading and unloading bulky and heavy goods from wagons.

Mobile crane This crane is mounted on a wagon or a truck and can be moved anywhere on the platform as per requirement to load or unload bulky parcels.

Overhead gantry cranes It consists of two horizontal girders or beams supported on a number of vertical posts. A travelling platform is fixed in between the two girders, which is fitted with equipment for hoisting goods and is capable of moving to and fro on the girders. Wagons or road vehicles are brought under the gantry for loading and unloading materials.

Foot Over Bridges and Subways

Foot over bridges is provided for the movement of passengers and light baggage from one platform to another. Bulky or heavy goods are taken from one platform to another by means of handcarts, which are carried across the tracks near the end of the platform in order to reach the requisite platform. Some stations are also provided with subways for the movement of the passengers and goods between platforms.

INTRODUCTION TO MODERN DEVELOPMENTS IN RAILWAYS

Railways are modernized with the objective of allowing heavier trains to run safely and economically at faster speeds, of improving productivity, and of providing better customer service to rail users. This consists of upgrading the track, use of better designed rolling stock, adopting a superior form of traction, better signaling and telecommunication arrangements, and using other modern techniques in the various operations of a railways system. A railway track is modernized by incorporating the following features in the track.

- Use of heavier rail sections such as 52 kg/m and 60 kg/m and the use of wear resistant rails for heavily used sections so as to increase the life of the rails.
- Use of curved switches of 1 in 16 and 1 in 20 type for smoother arrival at yards.
- Use of pre stressed concrete sleepers and elastic fastenings such as Pandrol clips to provide resilience to the track and ensure the smooth movement of trains at high speeds.
- Use of long welded rails and switch expansion joints to ensure a smooth and fast rail journey.
- Modernization of track maintenance methods to include mechanized maintenance, measured shovel packing, etc., in order to ensure better track geometry, to facilitate high speeds and smooth travel.
- Track monitoring using the Amsler car, portable accelerometer, Hallade track recorder, etc. to assess the standards of track maintenance and plan for better maintenance, if required.

Other aspects of modernization of the railways generally include making the following provisions.

- Use of better designed all-coiled, anti-telescope ICF coaches with better spring arrangements and better braking systems for safe and smoother rail travel.
- Provisions of universal couples to ensure uniformity in the coupling of the coaches.
- Introduction of diesel and electric traction in order to haul heavier loads at faster speeds.
- Introduction of modern signaling techniques to enable trains to move at high speeds without any risks.
- Setting up of a management information system for monitoring and moving freight traffic in order to avoid idle time and increase productivity.
- Computerization of the train reservation system to avoid human error and provide better customer service for reservation of berths.
- Use of computers and other modern management techniques to design and maintain railway assets more efficiently and economically, to ensure efficient human resource development (HRD), to increase productivity, and to provide better customer service.

SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – III – Railways, Airport and Harbour Engineering – SCIA1701

III. Points & Crossings, Signalling & Interlocking

Types of Points / Switch: Stub, Split switch - Types of crossing: acute angle, Obtuse angle, Square – Design calculation of Turnout - Various types of Track junctions - Signaling and Interlocking - Different types of signals, their working and location - Control systems of signals - Mechanical method of interlocking systems - Track circuiting.

INTRODUCTION

Points and crossings are provided to facilitate the change of railway vehicles from one track to another. The tracks may be parallel, diverging, or converging to each other. It is necessary due to the inside flanges of wheels of railway vehicles and, therefore require special arrangement to navigate their way on the rails. The points or switches aid in diverting the vehicles and the crossings provide gaps in the rails so as to help the flanged wheels to roll over them. A complete set of points and crossings, along with lead rails, is called a turnout.

Point and crossing assembly consists of three main Components namely ***Point, Lead and Crossing*** elements.

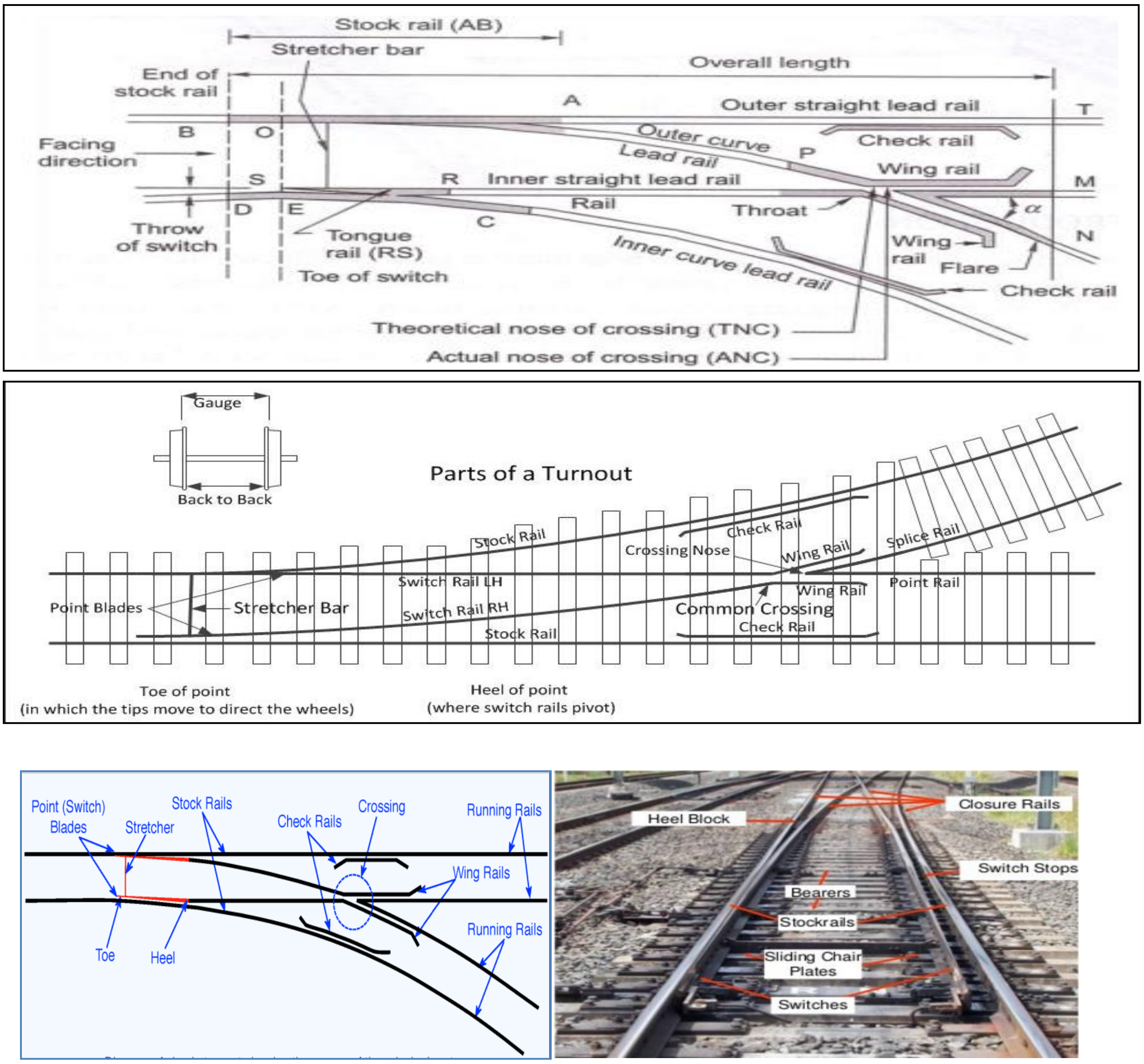
a) A ***point*** consists of one pair of tongue rails and Stock Rails with necessary fittings
b) ***Crossing*** is a device in the form of V-piece introduced in the track to permit movement of wheel flange at the inter section of two running lines. It has gap over which the wheel tread jumps
c) The track portion between point and crossing is called ***lead***.

Important Terms

Turnout - It is an arrangement of points and crossings with lead rails by means of which the rolling stock may be diverted from one track to another. The figure below shows the various constituents of a turnout.

Component Parts of a Turnout

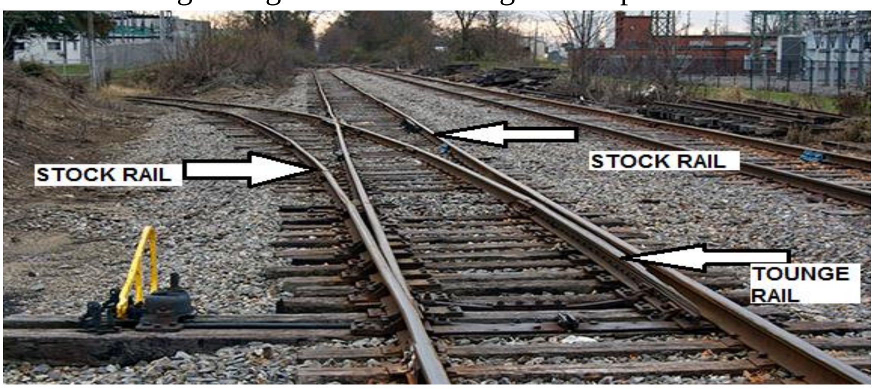
- A pair of tongue rails
- A pair of stock rails
- Two check rails
- Four lead rails
- V- crossing
- Slide chairs
- Stretcher bar
- A pair of heel blocks
- Switch tie plate or gauge
- Parts for operating points- Rods, cranks, levers etc



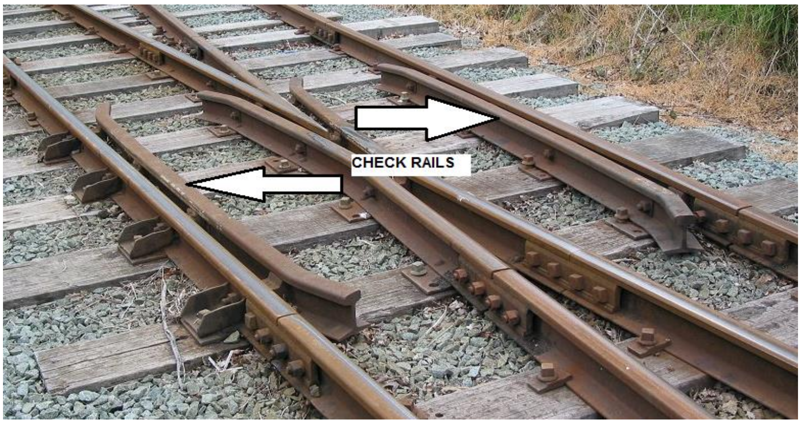
Components of turnout

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

Stock rail - It is the running rail against which a tongue rail operates.



Points or switch - A pair of tongue and stock rails with the necessary connections and fittings forms a switch.
Crossing - It is a device introduced at the junction where two rails cross each other to permit the wheel flange of a railway vehicle to pass from one track to another.
Switch angle **–** The angle between the gauge face of the stock rail and tongue rail at the theoretical toe of switch.
Vee crossing **–** It is to provide gaps between the tails to be crossed so that the wheel flanges can pass through the gaps without any obstruction.
Check rails **–** Its main function is to o check the tendency of wheels to climb over the crossing.



Switch Tie plate **–** It is to maintain gauge distance at front of switch
Slide Chairs **–** This is to support the tongue rails throughout their length.

Stretcher Bar - This is to connect toes of both the tongue rails so that each tongue rail moves through same distance.

Rods, Cranks, Lever – Its function is to operate the points

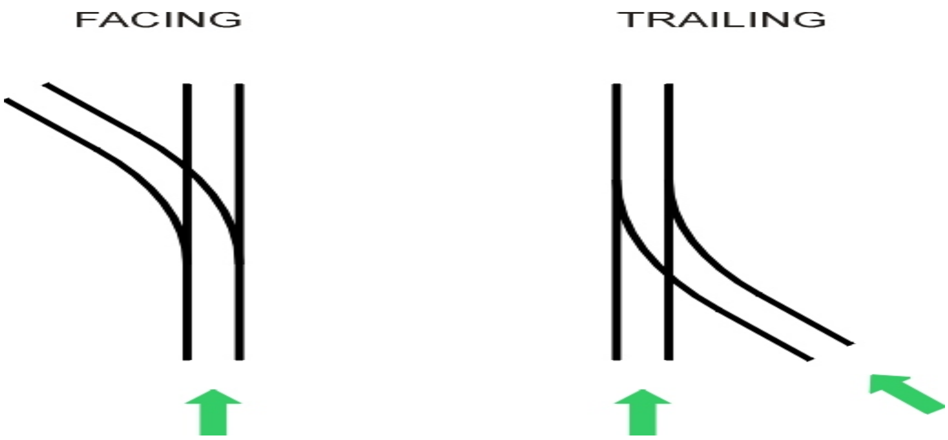
Throw of switch - The distance by which the tongue rail moves laterally at the toe of switch.

Heel of switch – It is an imaginary point on the gauge line midway between the end of lead rail and the tongue rail in case of loose heel switches In case of fixed heel switches; it is a point on the gauge line of tongue rail opposite the centre of heel block.

Lead – The track portion between heels of switch to the beginning of crossing assembly

Turn-in-curve – The track portion between the heel of crossing to the fouling marks

Facing and trailing direction - In Figure 1 the turnout is a right-hand turnout because it diverts the traffic towards the right side. The Figure 2 shows a left-hand turnout. The direction of a point (or turnout) is known as the *facing direction* if a vehicle approaching the turnout or a point has to first face the thin end of the switch. The direction is *trailing direction* if the vehicle has to negotiate a switch in the trailing direction, that is, the vehicle first negotiates the crossing and then finally traverses on the switch from its thick end to its thin end. Therefore, when standing at the toe of a switch, if one looks in the direction of the crossing, it is called the ***facing direction*** and the opposite direction is called the ***trailing direction***.



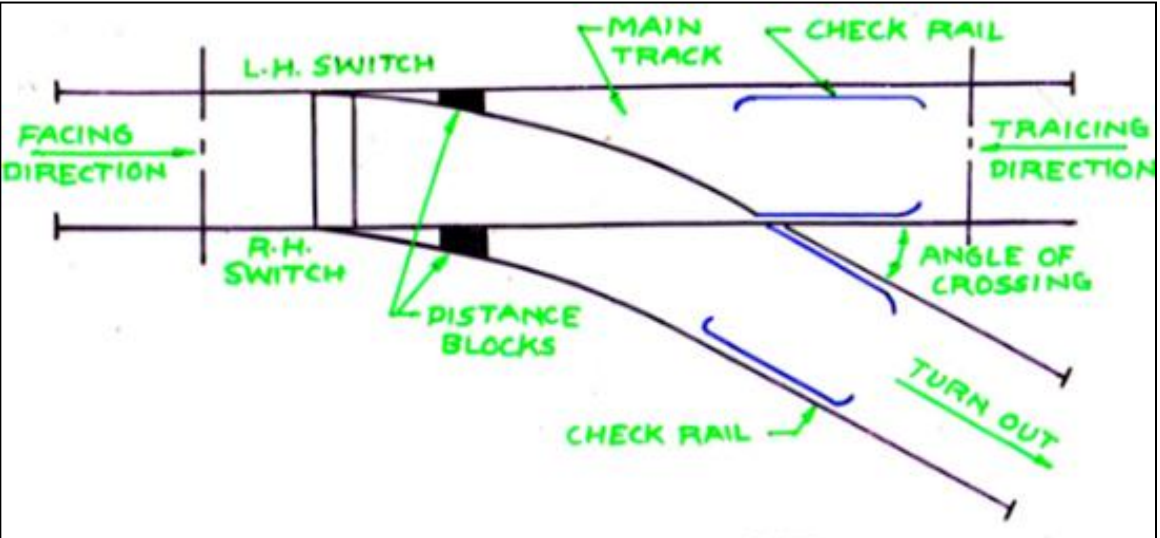


Fig. 1 A RIGHT-HAND TURNOUT

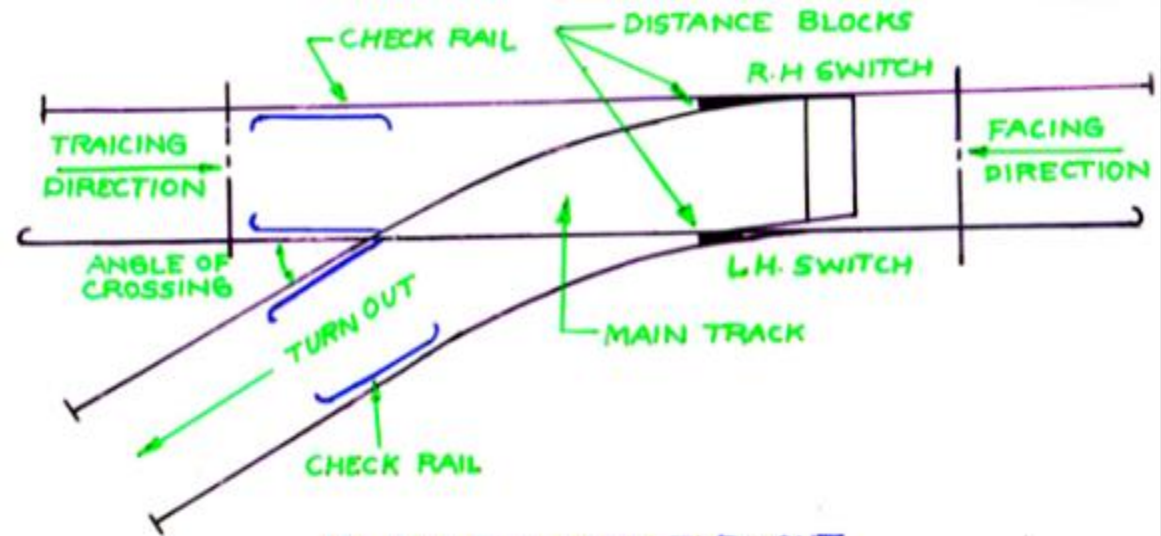
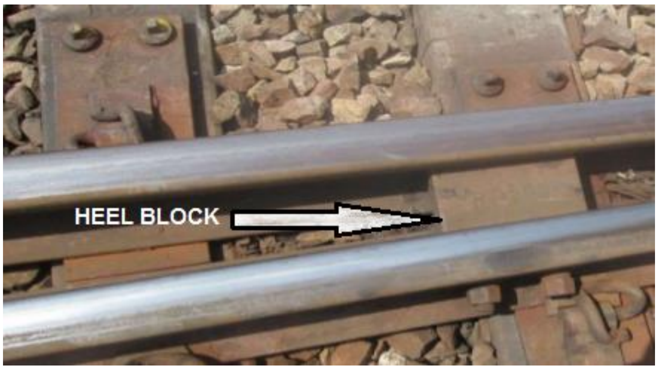


Fig. 2 A LEFT-HAND TURNOUT

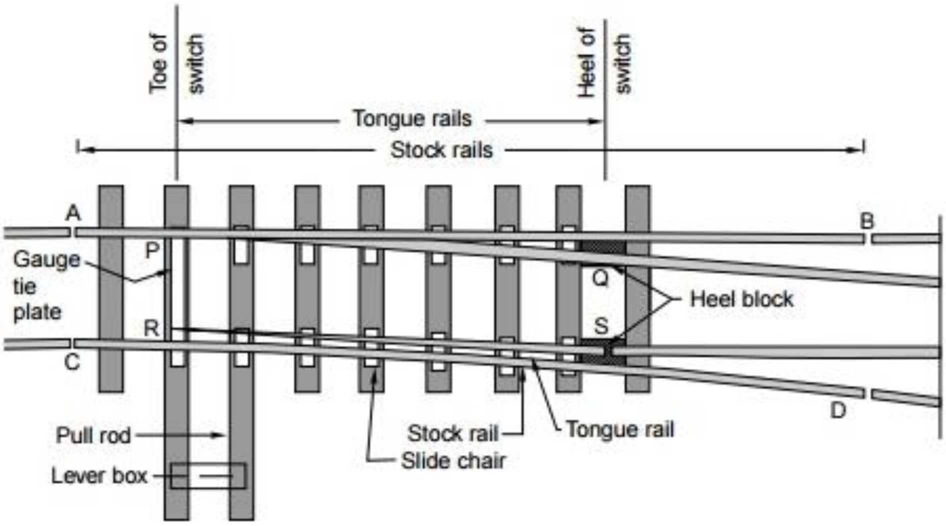
POINTS / SWITCHES

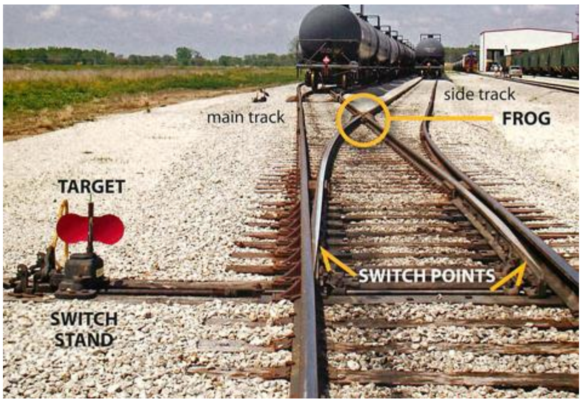
A set of points or switches consists of the following main constituents

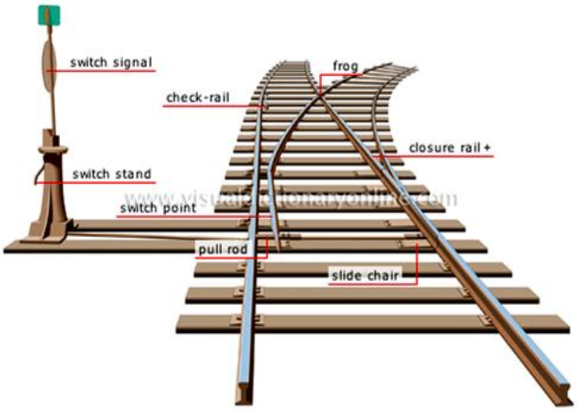
- A ***pair of stock rails***
- A ***pair of tongue rails*** also known as switch rails, made of medium-manganese steel to withstand wear. The tongue rails are machined to a very thin section to obtain a comfortable fit with the stock rail. The tapered end of the tongue rail is called the *toe and the thicker end is called the heel.*
- A ***pair of heel blocks*** which hold the heel of the tongue rails is held at the standard clearance or distance from the stock rails.

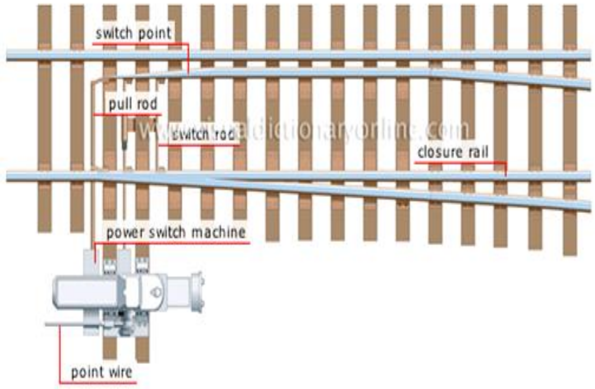


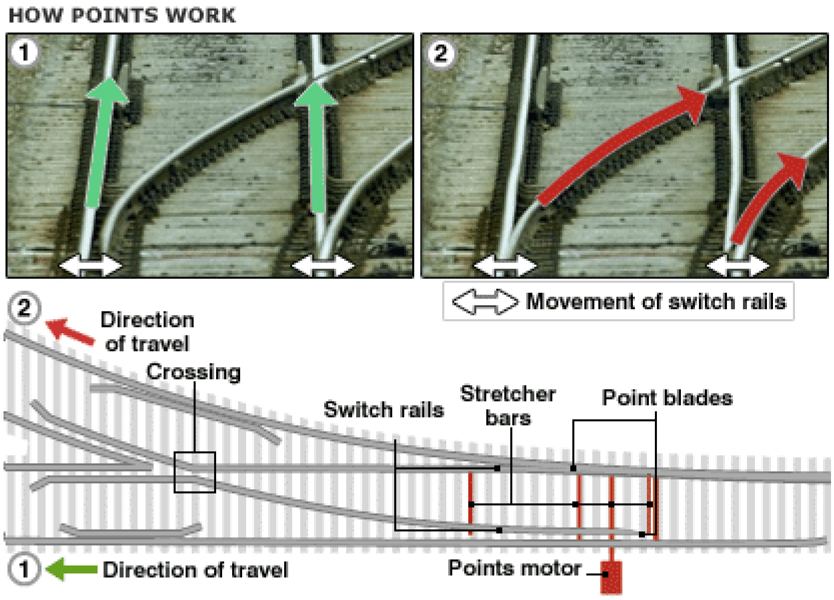
- A ***number of slide chairs*** to support the tongue rail and enable its movement towards or away from the stock rail.
- Two or more ***stretcher bars*** connecting both the tongue rails close to the toe, for the purpose of holding them at a fixed distance from each other
- A ***Gauge tie plate*** to fix gauges and ensure correct gauge at the points.





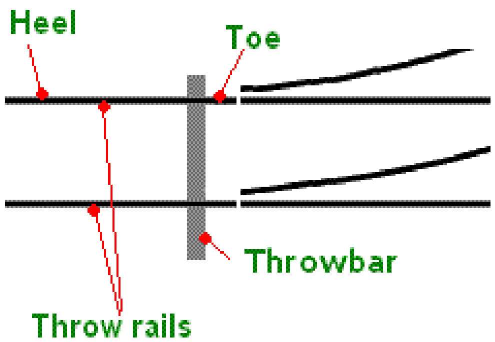






Types of switches

1. Stud switch - No separate tongue rail is provided and some portion of the track is moved from one side to the other side. The throw of switch was about 5 inches. It is not in use and is replaced by split switch.

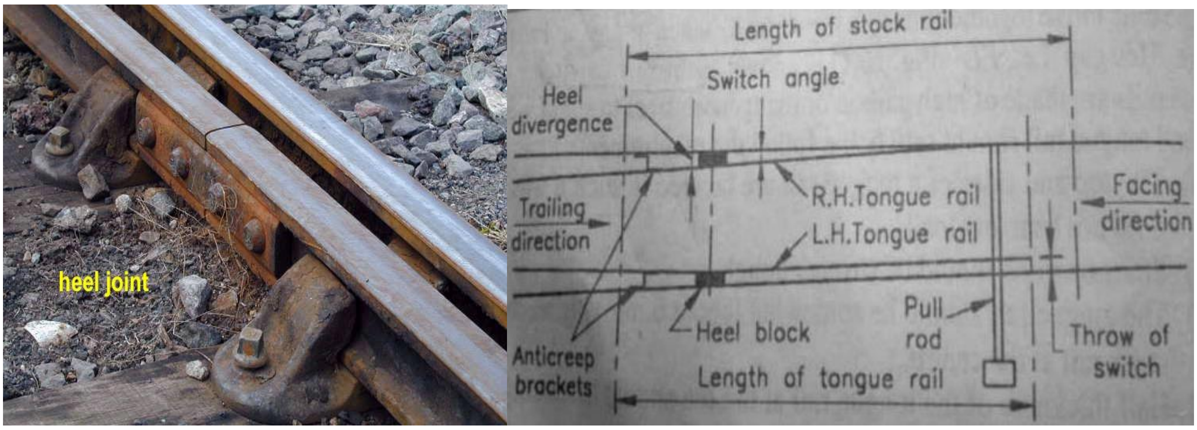


Stud switch

2. Split switch - These consist of a pair of stock rails and a pair of tongue rails. These are 2 types
    a. Loose heel type
    b. Fixed heel type

<u>Loose heel type</u>

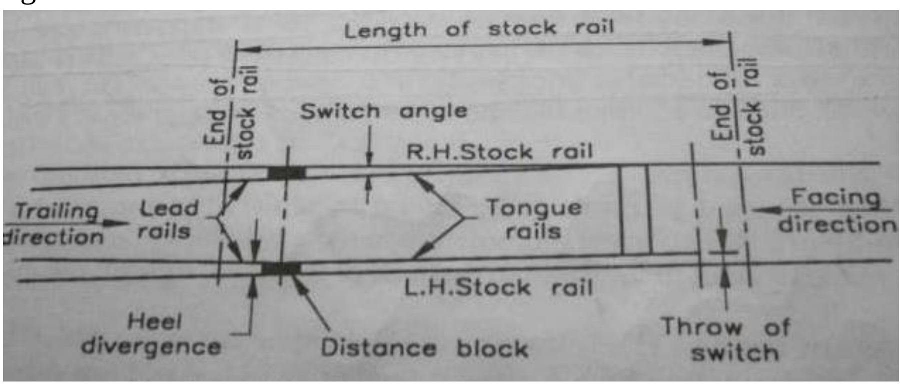
- In this type of split switch, the switch or tongue rail finishes at the heel of the switch to enable movement of the free end of the tongue rail.
- The fish plates holding the tongue rail may be straight or slightly bent.
- The tongue rail is fastened to the stock rail with the help of a fishing fit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



Loose heel type

<u>Fixed heel type</u>

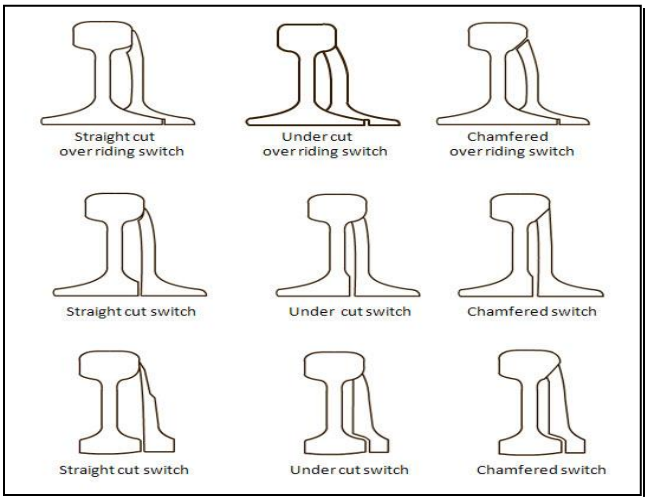
- In this type of split switch, the tongue rail does not end at the heel of the switch but extends further and is rigidly connected.
- The movement at the toe of the switch is made possible on account of the flexibility of the tongue rail.

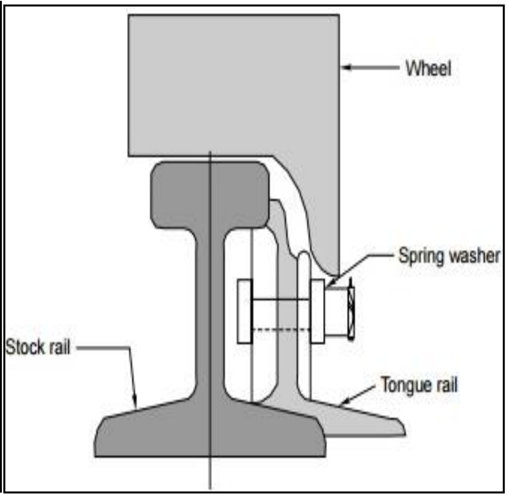


Fixed heel type

Based on Toe of Switches

1. *Undercut switch* - The foot of the stock rail is planned to accommodate the tongue rail
2. *Straight cut switch* - Tongue rail is cut straight along the stock rail to increase thickness at toe.
3. *Over riding switch*
   - Stock rail occupies the full section and the tongue rail is planed to a 6mm thick edge which overrides the foot of stock rail
   - Switch rail is kept 6mm higher than the stock rail from the heel to the point towards the toe where planning starts
   - Eliminates the possibility of splitting which might be caused by the movement of false flange in the trailing direction
   - Stock rail is uncut, hence more stronger manufacturing work is confined only to tongue rail, which is very economical
   - Tongue rail supported by stock rail, hence combined strength of rails between sleepers is greater than that of tongue rail alone in the case of undercut switch.
   - These overriding switches are standardized and used in IR.





Undercut and straight cut Switch ***Overriding Switch***

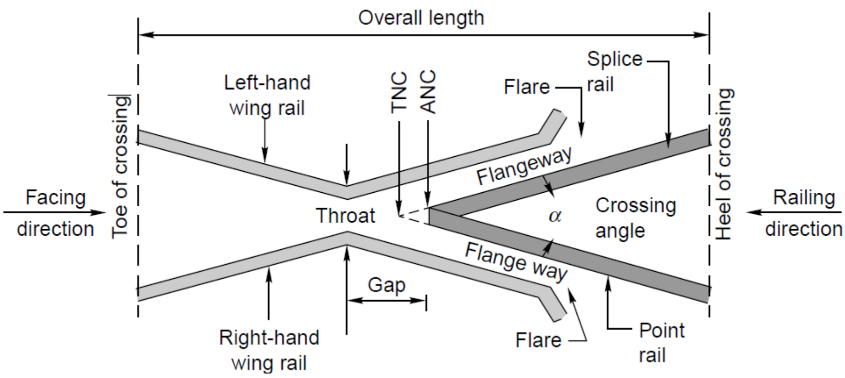
CROSSINGS

- A crossing or *frog is a device introduced at the point where two gauge faces cross* each other to permit the flanges of a railway vehicle to pass from one track to another.
- A gap is provided from throw to the nose of crossing
- Check rails assures the correct movement and guides the wheels properly.

Crossings

Components of crossings

- Two types of rails – Point rail, Splice rail. These are machined to form a nose.
- The *point rail* has its fine end slightly cut off to form a blunt nose, with a thickness of 6 mm.
- The toe of the blunt nose is called the *actual nose of crossing* (ANC) and the theoretical point where gauge faces from both sides intersect is called the *theoretical nose of crossing* (TNC).
- The '*V' rail* is planed to a depth of 6 mm at the nose and runs out in 89 mm to stop a wheel running in the facing direction from hitting the nose.
- Two *wing rails* consisting of a right-hand and a left-hand wing rail that converge to form a throat and diverge again on either side of the nose.
- *Wing rails* are flared at the ends to facilitate the entry and exit of the flanged wheel in the gap.
- A pair of *check rails* are used to guide the wheels

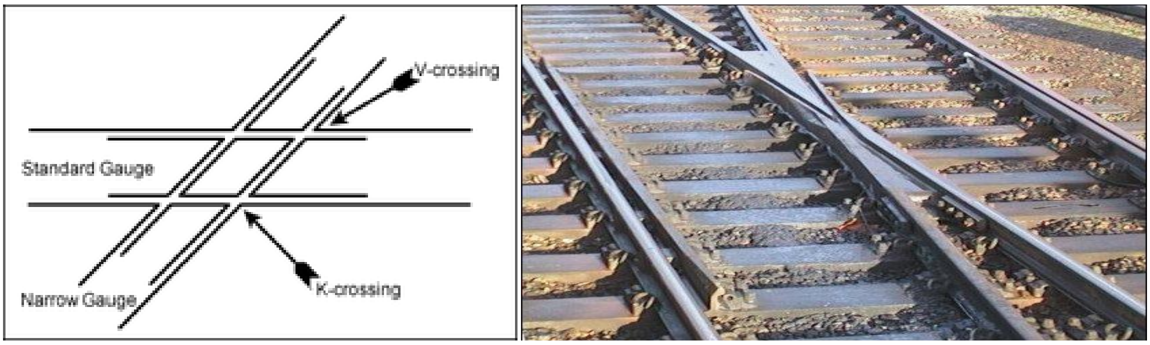


Types of crossings

Based on the angle of crossing

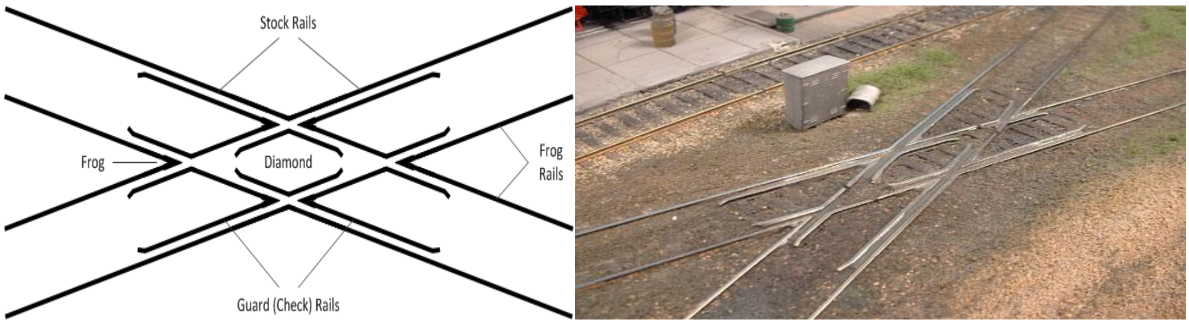
1. ***Acute angle crossing or V crossing*** - 2 rail gauge faces cross at acute angle
2. ***Obtuse angle or Diamond crossing*** - 2 gauge faces meet at obtuse angle
3. ***Square crossing*** - Two tracks cross at right angles

Acute angle crossing or V crossing - Acute angle crossing is formed when left hand rail of one track crosses right hand rail of another track at an acute angle or vice versa. This type of crossing consists of a pair of wing rails, a pair of check rail and a splice rail. This crossing is widely used. This is also called V-crossing or frog.



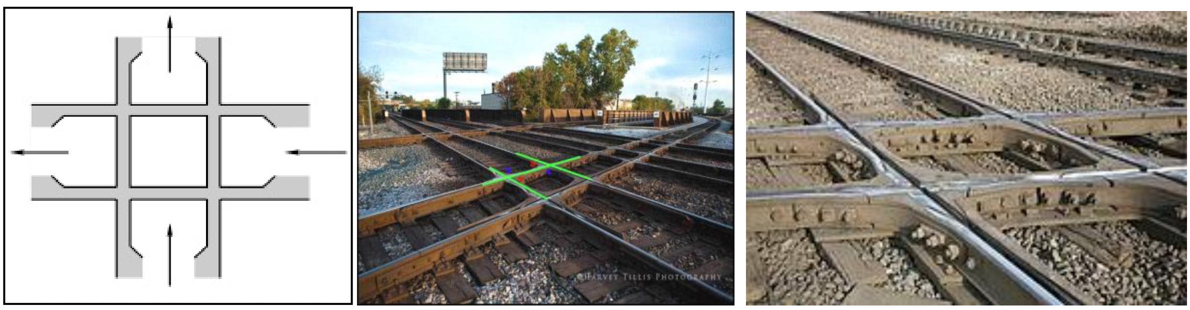
Acute angle crossing or V crossing

Obtuse angle or Diamond crossing - Obtuse crossing is formed when left hand rail of one track crosses right hand rail of another track at an obtuse angle or vice versa. This type of crossing consists mainly of two acute and two obtuse angle crossings. This is also called Diamond crossing.



Obtuse angle or Diamond crossing

Square crossing - Square Crossing is formed when two straight tracks of same or different gauge, cross each other at right angles. This type of crossing should be avoided on main lines because of heavy wear of rails.



Square crossing

DESIGN CALCULATION OF TURNOUT

The ***main features*** of the design of these turnouts are the following.

- Long curved switches are provided to avoid the abrupt change in the direction of the vehicle at the entry to the switch.
- Switches and crossings are curved to the same radius as the lead curve or, alternatively, a transition curve is provided between the toe of the switch and the nose of the crossing. This provides a smooth passage to the trains on the turnout curve.
- Higher cant deficiency is permitted so that the disadvantage of not providing superelevation on the turnout curve is duly compensated.

The ***main factors*** responsible for low speeds over turnouts on Indian Railways are as follows.

- A sudden change in the direction of the running edge upon entry onto the switch from a straight track
- Absence of a transition between the curved lead and the straight crossing
- Non-transitioned entry from the curved lead to the straight crossing
- Absence of superelevation over the turnout curve
- Gaps in the gauge face and the running table at the crossing
- Variation in cross level caused by raised switch rails

DESIGNING OF A TURNOUT

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

(a) Coles method and

(b) IRS method.

These methods are described in detail in the following sections. The important terms used in describing the design of turnouts are defined as follows.

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

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

Lead of crossing (L) - This is the distance measured along the length of the main track as follows:

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

Gauge (G) This is the gauge of the track.

Heel divergence (D) - This is the distance between the main line and the turnout side at the heel.

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

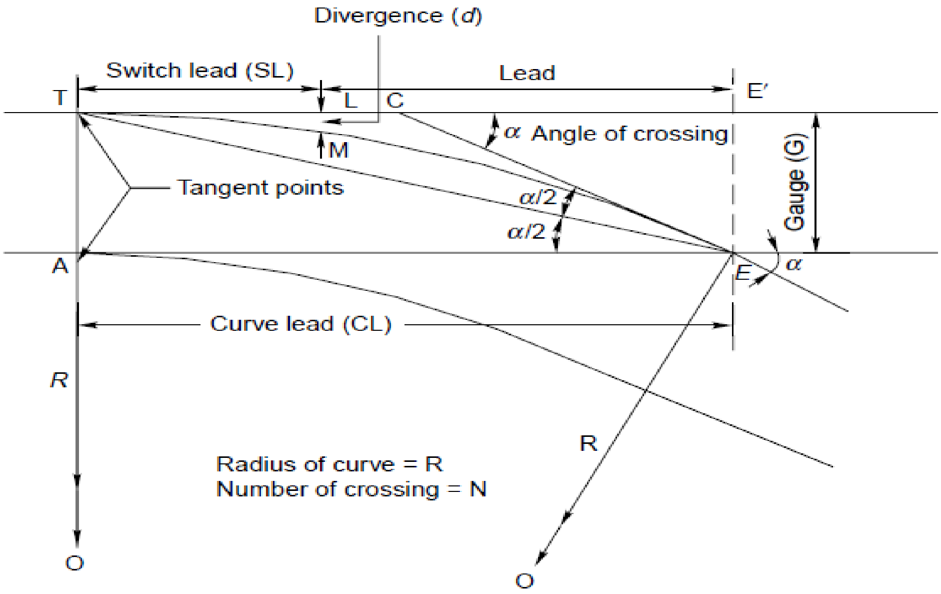
Radius of turnout (R) - This is the radius of the turnout. It may be clarified that the radius of the turnout is equal to the radius of the centre line of the turnout ($R1$) plus half the gauge width.

$$\boldsymbol{R = R1 + 0.5G}$$

As the radius of a curve is quite large, for practical purposes, *R* may be taken to be equal to *R*1.

(a) Coles method

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



a) The first kink is formed at the actual toe of the switch.
b) The second kink is formed at the heel of the switch.
c) The third kink is formed at the first distance block of the crossing.

The notations used in the above figure are the following:

Curve lead (CL) = AE = TE′

Switch lead (SL) = TL

Lead of crossing (*L*) = LE′

Gauge of track (*G*) = AT = EE′

Angle of the crossing (a) = ÐCEA = ÐECE¢

Heel of divergence (*d*) = LM

Number of the crossing (*N*) = cota

Radius of outer rail of turnout curve (*R*) = OE = OT

(O is the centre of the turnout curve)

Calculations

Curve lead (CL) In ΔATE,

$$\text{AT} = G \text{ and } \angle\text{AET} = \frac{\alpha}{2}$$

$$\tan\frac{\alpha}{2} = \frac{\text{AT}}{\text{AE}} = \frac{G}{\text{curve lead}}$$

or

$$\text{Curve lead} = G\cot\frac{\alpha}{2}$$

Also,

$$\begin{aligned}\text{Curve lead} &= \text{E'C} + \text{CT}\\ &= \text{E'C} + \text{CE (as CT = CE)}\\ &= G\cot\alpha + G\operatorname{cosec}\alpha\\ &= GN + G\sqrt{1+N^2}\ (as\ \cot\alpha = N)\end{aligned}$$

or

$$= 2GN \text{ (approximately)}$$

Switch lead (SL) TL is the length of the tangent with an offset LM = D = heel divergence.

From the properties of triangles,

$$\text{SL} \times \text{SL} = d(2\text{R} - d)$$

or

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

Lead of crossing (L)

$$L = \text{curve lead} - \text{switch lead}$$

$$= G\cot\frac{\alpha}{2} - \sqrt{2Rd - d^2}$$

Radius of curve (R) In ΔAOE,

$$\text{OE} = \text{OT} = R,\ \text{OA} = R - G$$

$$\text{OE}^2 = \text{OA}^2 + \text{AE}^2$$

$$\text{OE}^2 = (\text{R} - \text{G})^2 + (\text{curve lead})^2$$

or,

$$R^2 = (R-G)^2 + (GN + G\sqrt{1+N^2})$$

$$= R^2 - 2RG + G^2 + G^2N + G^2(1+N^2) + 2\,G^2N\sqrt{1+N^2}$$

$$2RG = 2G^2(1+N^2) + 2G^2N\sqrt{1+N^2}$$

or

$$R = G(1+N^2) + GN\sqrt{1+N^2}$$

$$= 1.5G + 2GN^2 \text{ (approximately)}$$

Summarizing the formulae derived,

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

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

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

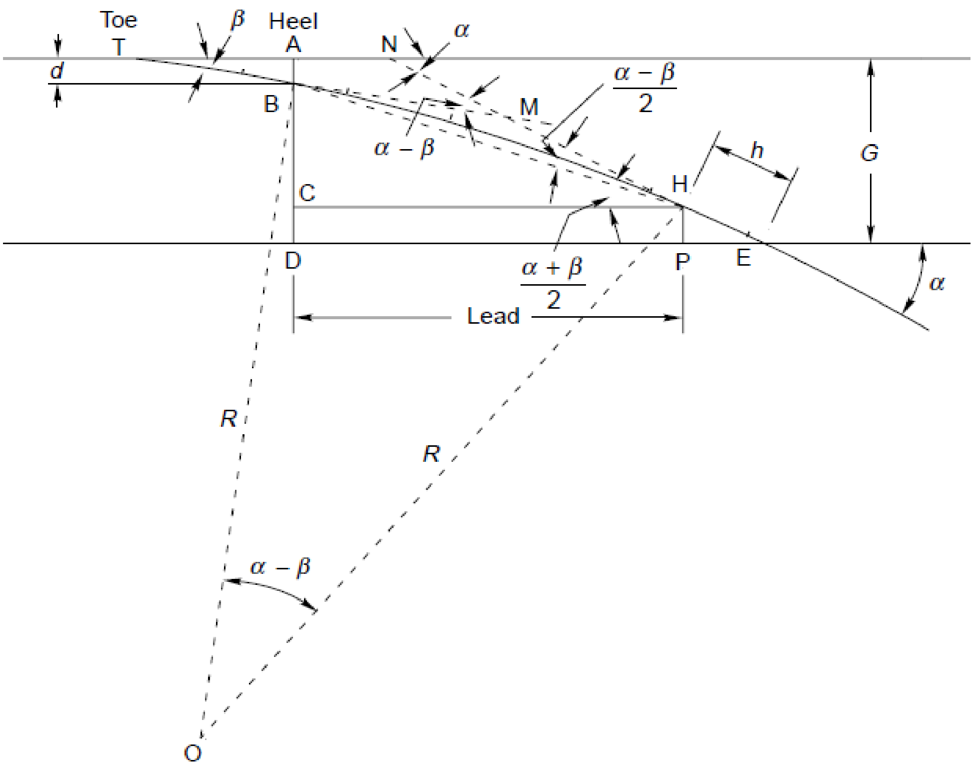
$$= 2GN - \sqrt{2Rd - d^2}$$

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

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

IRS method

In this layout as given in the figure below, the curve begins from the heel of the switch and ends at the toe of the crossing, which is at the centre of the first distance block. The crossing is straight and no kink is experienced at this point. The only kink occurs at the toe of the switch. This is the standard layout used on Indian Railways. The calculations involved in this method are somewhat complicated and hence this method is used only when precision is required.



Lead of crossing (L)

In ΔBMH,
BM = MH (as both are tangents)
□MHB = □MBH = (α - β)/2
BC = AD – (AB + CD) = *G* – (*d* + *h* sin α)
Therefore, crossing lead

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

Radius of curve (R) DOBH,
ΔBOH = α – β

$$\mathrm{BH} = 2R\ \sin\frac{\alpha - \beta}{2}$$

In ΔBHC,

$$\mathrm{BH} = \frac{\mathrm{BC}}{\sin\frac{\alpha+\beta}{2}} = \frac{G - d - h\sin\alpha}{\sin\frac{\alpha + B}{2}}$$

Equating Eqns (14.7) and (14.8)

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

or

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

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

<u>Turnout with Curved Switches</u>

The following formulae are used for the calculation of turnouts with curved switches

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

$$I = R\ \sin\alpha - (G - t - h\ \sin\alpha)\ \cot\frac{\alpha+\beta}{2}$$

$$V = G - \{h\ \sin\alpha + R(1 - \cos\alpha)\}$$

$$\text{Switch lead } = \sqrt{2R(d-y) - (d-y)^2 - 1}$$

$$\text{Lead} = (G - t - h\ \sin\alpha)\ \cot\frac{\alpha+\beta}{2} - \mathrm{SL} - h\ \cos\alpha$$

Where,
R is the radius of the outer lead rail,

G is the gauge,
h is the lead of the straight leg of the crossing ahead of TNC up to the TP of the lead curve,
t is the thickness of the switch at the toe,
I is the distance from the toe of the switch to the point where the tangent drawn to the extended lead curve is parallel to the main line gauge face,
V is the distance between the main line gauge face and the tangent drawn to the lead curve from a distance l from the toe,
y is the vertical ordinate along the Y-axis,
α is the crossing angle, and
β is the switch angle.

TRACK JUNCTIONS

Track junctions are formed by the combination of points and crossings. Their main objective is to transfer rail vehicles from one track to another or to enable them to cross from one track to another. Depending upon the requirements of traffic, there can be several types of track junctions with simple track layouts.

<u>Various types of Track Junctions</u>

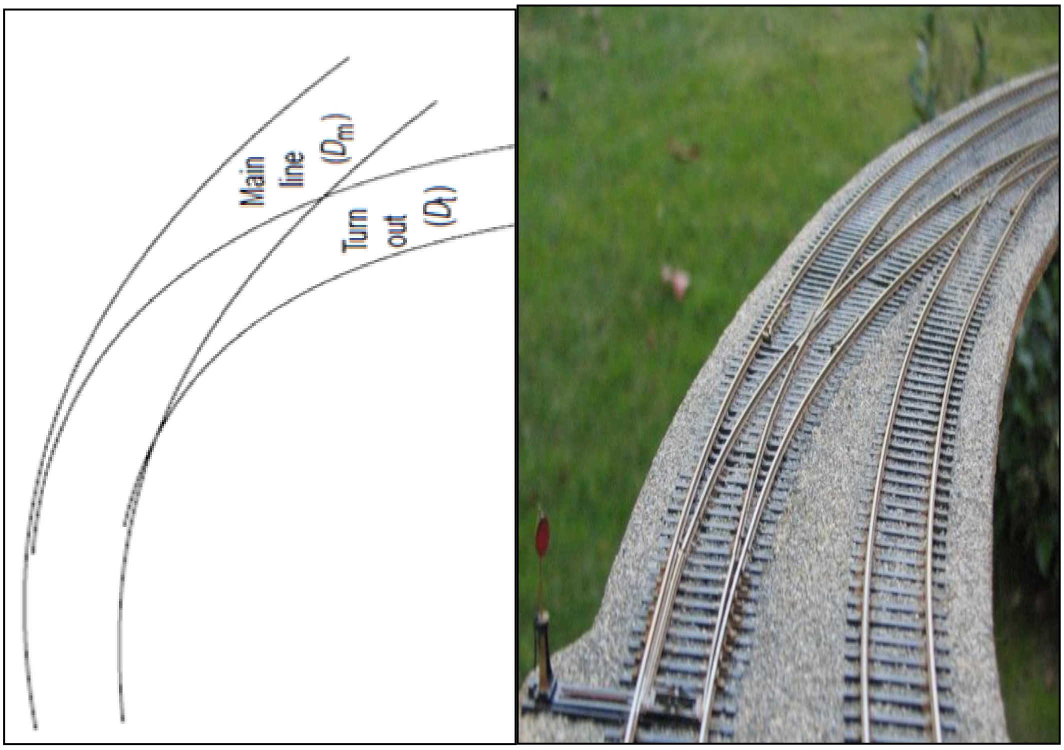
Turnout of Similar Flexure

A turnout of similar flexure is one that continues to run in the same direction as the main line curve even after branching off from it. The degree of the turnout curve is higher than that of the main line curve. The degree and radius of the turnout curve are given by the formulae

$$D_t = D_s + D_m$$

$$R_t = \frac{R_m \, R_s}{R_m + R_s}$$

Where,
D_s is the degree of the outer rail of the turnout curve from the straight track,
D_m is the degree of the rail of the main track on which the crossing lies, i.e., the inner rail,
D_t is the degree of the rail of the turnout curve on which the crossing lies, i.e., the outer rail,
R_s is the radius of the outer rail of the turnout curve from the straight track, and
R_t is the radius of the rail of the turnout curve on which the crossing lies, i.e., the outer rail.



Turnout of Similar Flexure

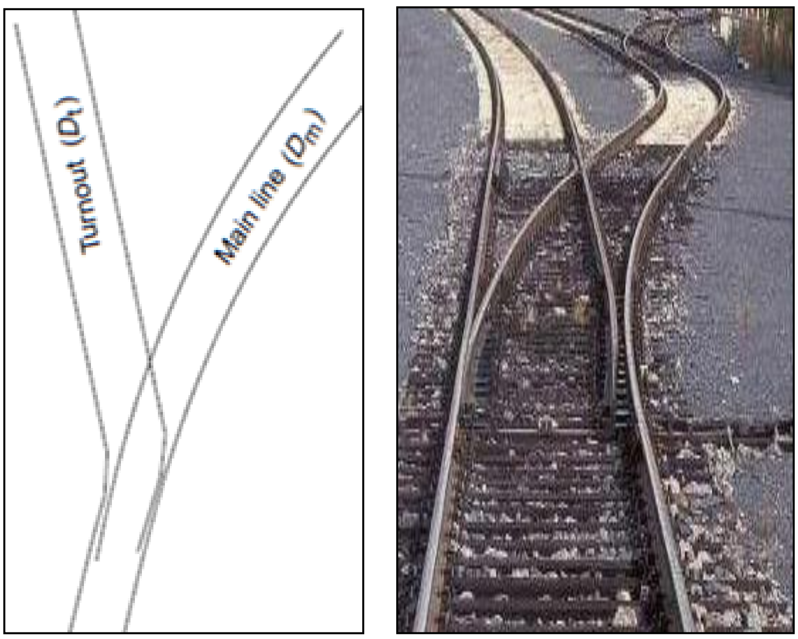
Turnout of Contrary Flexure

A turnout of contrary flexure is one that takes off towards the direction opposite to that of the main line curve. In this case, the degree and radius of the turnout curve are given by the following formulae:

$$D_t = D_s - D_m$$

$$R_t = \frac{R_s \ R_m}{R_m - R_s}$$

Here *D*m is the degree of the rail of the main track on which the crossing lies, i.e., the outer rail



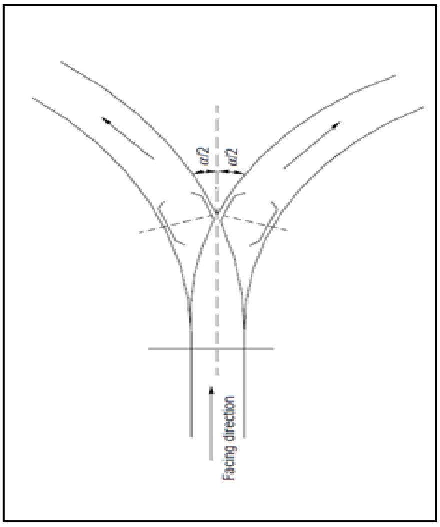
Turnout of Contrary Flexure

Symmetrical Split

When a straight track splits up in two different directions with equal radii, the layout is known as a symmetrical split. In other words, a symmetrical split is a contrary flexure in which the radii of the two curves are the same.

The salient features of a symmetrical split are the following.

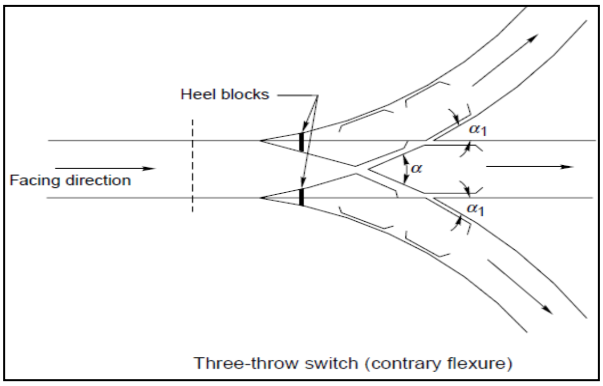
- The layout consists of a pair of points, one acute angle crossing, four curved lead rails, and two check rails.
- The layout is symmetrical about the centre line. This means that the radii of the main track as well as of the branching track are equal.
- The layout provides facilities for diverting vehicles both towards the left and the right.
- It is suitable for locations with space constraints, as it occupies comparatively much less space than a turnout from the straight track.

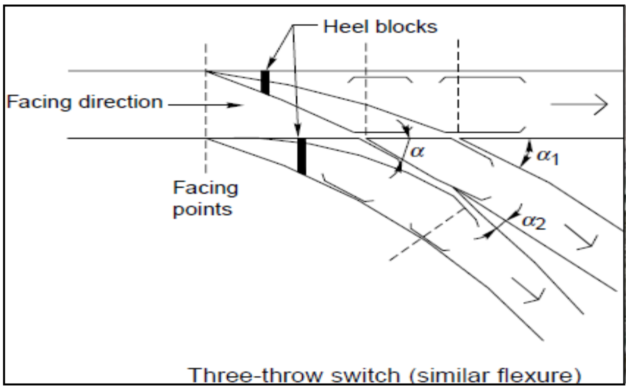


Symmetrical Split

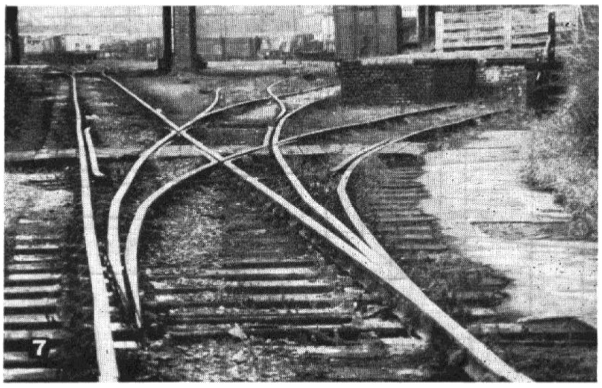
Three-throw Switch

In a three-throw arrangement, two turnouts take off from the same point of a main line track. A three-throw switch can have contrary flexure or similar flexure, as shown. Three-throw switches are used in congested goods yards and at entry points to locomotive yards, where there is a great limitation of space.





Three-throw switch (similar flexure)

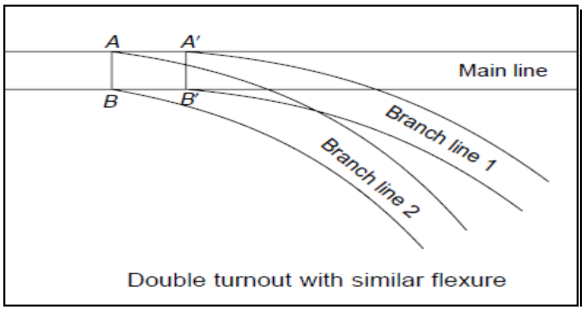


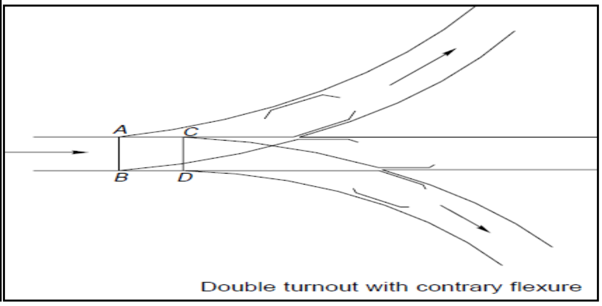
A three-throw switch has two switches and each switch has two tongue rails placed side by side. There is a combined heel block for both the tongue rails of the switch. The switches can be operated in such a way that movement is possible in three different directions, i.e., straight, to the right, and to the left. Three-throw switches are obsolete now as they may prove to be hazardous, particularly at higher speeds, because the use of double switches may lead to derailments.

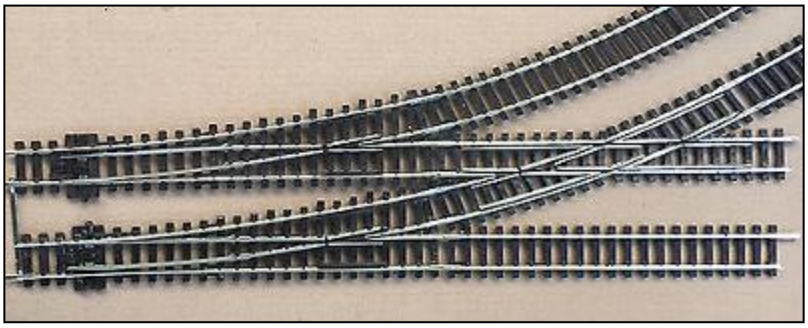
Double Turnout

A double turnout or *tandem* is an improvement over a three-throw switch. In a double turnout, turnouts are staggered and take off from the main line at two different places. This eliminates the defects of a three-throw switch, as the heels of the two switches are kept at a certain distance from each other. The distance between the two sets of switches should be adequate to allow room for the usual throw of the point.

Double turnouts can be of similar flexure, when the two turnouts take off on the same side of track or of contrary flexure, when the two turnouts take off in two different directions. Double turnouts are mostly used in congested areas, particularly where traffic is heavy, so as to economize on space.

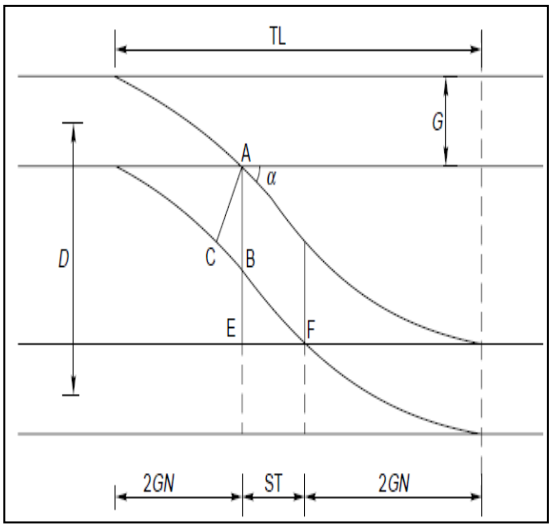






Crossover between Two Parallel Tracks with an Intermediate Straight Length

The crossover between two parallel tracks with an intermediate straight length can be designed by applying any one of two methods.



Coles design

Coles design is a simple layout. In this case, two parallel tracks at a distance D from each other are connected by a crossover with a small length of the straight portion of the track lying between the two theoretical noses of the crossing. The straight portion of the track (ST) can be calculated using the formula

$$\text{Straight track (ST)} = (D - G)N - G\sqrt{1 + N^2}$$

Where, G is the gauge of the track and N is the number of the crossing.

The overall length (OL) of the crossover from the tangent point of one track to the tangent point of the other track is found by adding the lengths of the curve leads of the two turnouts and the length of the straight portion in between the two TNC

$$\begin{aligned}\text{Overall length} &= \text{OL of one turnout} + \text{ST} + \text{OL of other turnout}\\ &= 2GN + (D - G)N - G\sqrt{1 + N^2} + 2GN\\ &= (D - G)N + G(4N - \sqrt{1 + N^2})\end{aligned}$$

Since the value of N^2 is very large as compared to 1, the value $\sqrt{(1 + N^2)}$ can be taken approximately as N. Simplifying the above equation,

$$\begin{aligned}\text{Total length (TL)} &= (D + 2G)N\\ &= 2GN + \text{ST} + 2GN\\ &= 4GN + \text{ST}\end{aligned}$$

IRS design

In IRS design, the distance from the TNC measured along the straight track is given by the formula

$$\text{ST} = (D - G - G\sec\alpha)\cot\alpha$$

On simplification

$$\text{ST} = D\cot\alpha - G\cot\alpha/2$$

Where,

ST is the distance from TNC to TNC along the straight track,

D is the distance from centre to centre of two tracks,

G is the gauge, and

α is the angle of crossing.

Similarly, the distance from TNC to TNC along the crossover is given by the formula

$$\text{CF} = (D - G - G\sec\alpha)\operatorname{cosec}\alpha + G\tan\alpha$$

Where,

CF is the distance from TNC to TNC along the crossover,

D is the distance from centre to centre of two tracks,

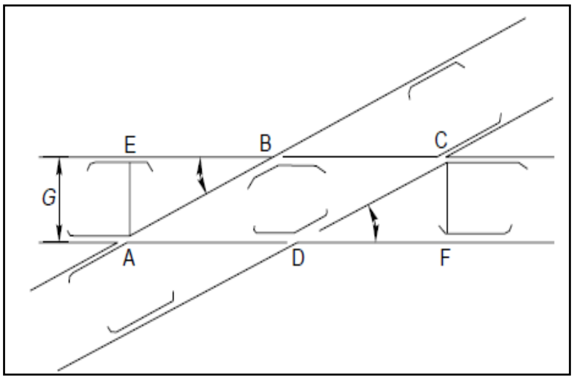
G is the gauge, and

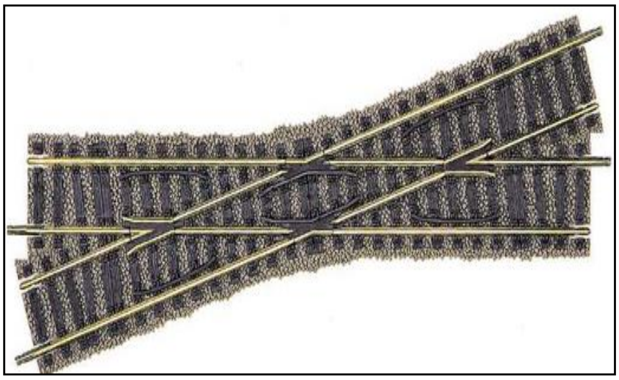
α is the angle of crossing.

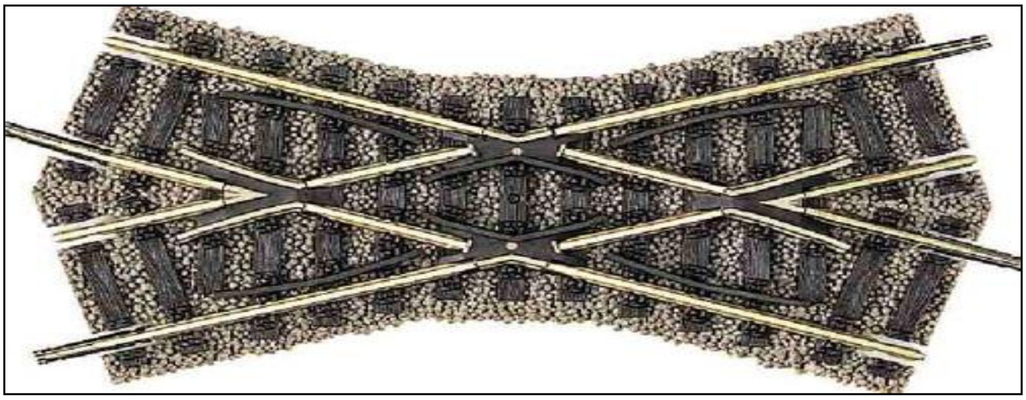
Diamond Crossing

A diamond crossing is provided when two tracks of either the same gauge or of different gauges cross each other. It consists of two acute crossings (A and C) and two obtuse crossings (B and D). A typical diamond crossing consists of two tracks of the same gauge

crossing each other. It can be seen from the layout that the length of the gap at points B and D increases as the angle of crossing decreases. Longer gaps increase the chances of the wheels, particularly of a small diameter, being deflected to the wrong side of the nose. On Indian Railways, the flattest diamond crossing permitted for BG and MG routes is 1 in 8.5.
Along with diamond crossings, ***single or double slips*** may also be provided to allow the vehicles to pass from one track to another.



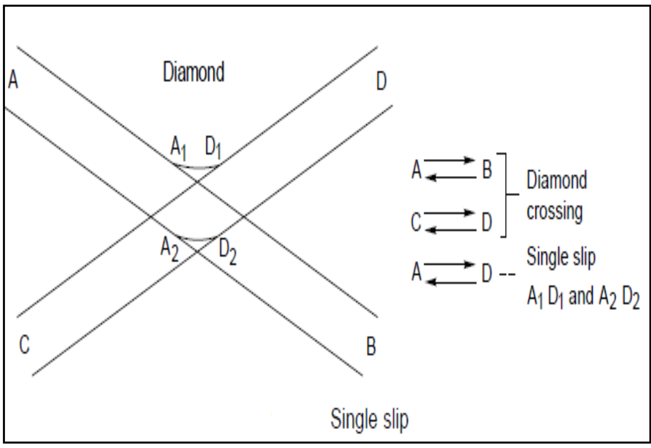




Single Slip and Double Slip

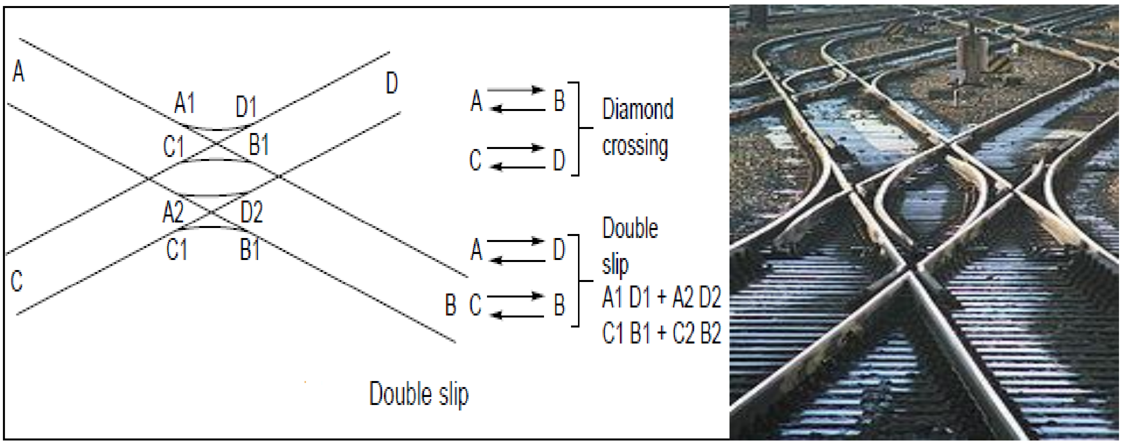
In a diamond crossing, the tracks cross each other, but the trains from either track cannot change track. Slips are provided to allow vehicles to change track. The slip arrangement can be either single slip or double slip.

In *single slips*, there are two sets of joints; the vehicle from only one direction can change tracks. In the single slip shown in figure, the train on track A can change to track D, whereas the train on track C remains on the same track, continuing onto track D.



Single Slip diamond cross over

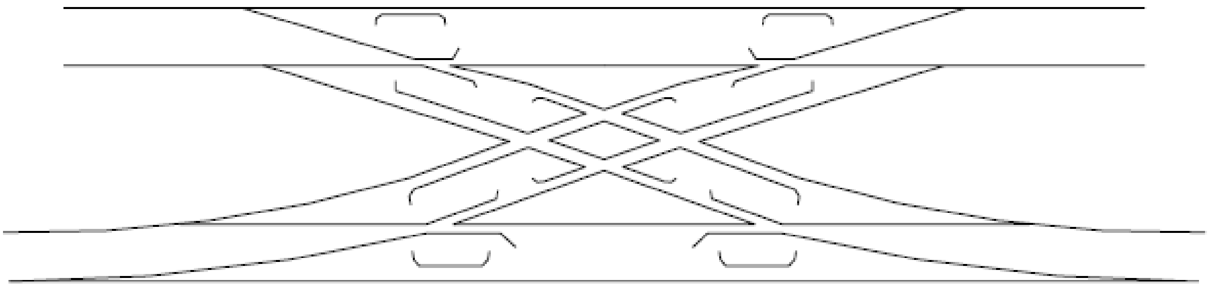
In *double slips*, there are four sets of points, and trains from both directions can change tracks. In the double slip shown in figure, the trains on both tracks A and C can move onto either track B or D.

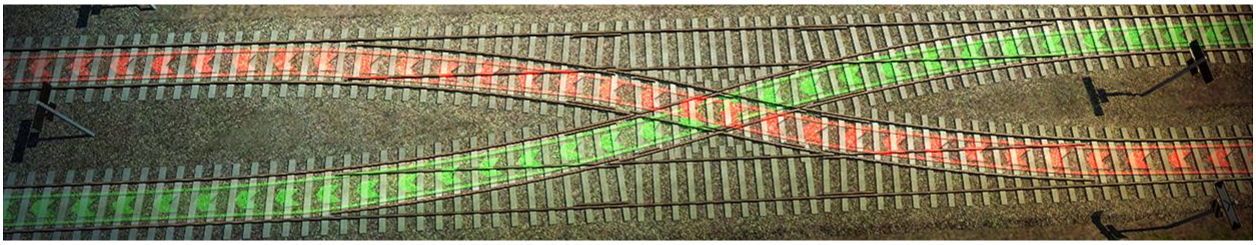


Double Slip diamond cross over

Scissors Crossover

A scissors crossover is meant for transferring a vehicle from one track to another track and vice versa. It is provided where lack of space does not permit the provision of two separate crossovers. It consists of four pairs of switches, six acute crossings, two obtuse crossings, check rails, etc.



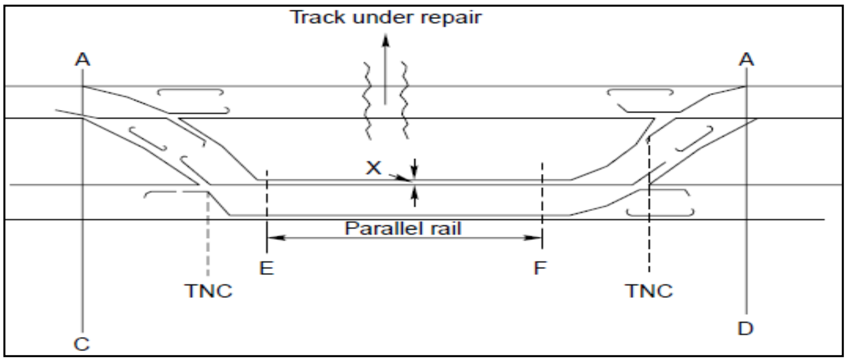


The scissors crossovers commonly used are of three types depending on the distance between the two parallel tracks they join. A brief description of these crossovers follows.

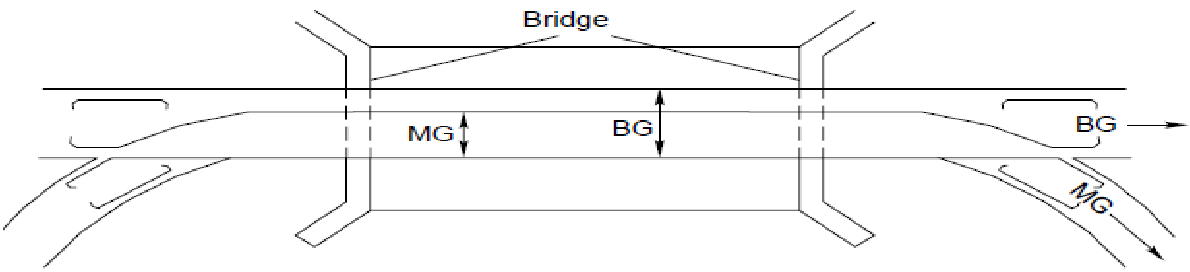
a) In the first type, the acute crossing of the diamond falls within the lead of the main line turnout. In this case, the lead of the main line turnout is considerably reduced and hence this is not a satisfactory arrangement.
b) In the second type, the acute crossing of the diamond falls opposite the crossing of the main line turnout. Here, both the crossings lie opposite each other, resulting in a simultaneous drop of the wheel and this result in jolting. This is also not a desirable type of layout.
c) In the third type of scissors crossover, the acute crossing falls outside the lead of the main crossing. Thus, the acute crossing of the diamond is far away from the crossing of the main line track. This is the most satisfactory arrangement out of these three layouts.

Gauntlet Track

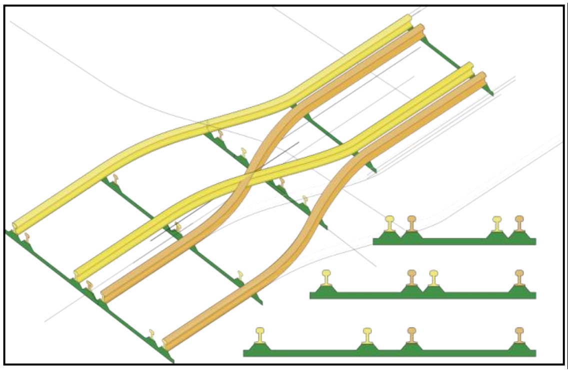
This is a temporary diversion provided on a double-line track to allow one of the tracks to shift and pass through the other track. Both the tracks run together on the same sleepers. It proves to be a useful connection when one side of a bridge on a double-line section is required to be blocked for major repairs or rebuilding. The specialty of this layout is that there are two crossings at the ends and no switches.

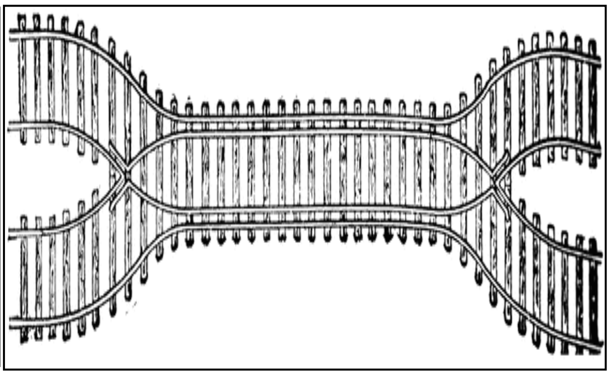


Gauntleted tracks are also used on sections where trains have to operate on mixed gauges, say, both BG and MG, for a short stretch. In such cases both the tracks are laid on the same set of wooden sleepers



Gauntletted track for mixed gauge





The salient features of the gauntleted track are as follows.

a) Two tracks are laid on the same sleepers with two sets of crossings without any switches.
b) Gauntleted tracks can be economically used for mixed gauge, i.e., say, for tracks with both BG and MG.
c) This layout is used when part of a double-line bridge is under repair. It is also used to economize the cost of a double-line bridge.

Gathering Line

A gathering line (also called a *ladder track*) is a track where a number of parallel tracks gather or merge. Alternatively, a number of parallel tracks also branch off from a gathering line. A gathering line is defined by the turnout angles and the angle of inclination of the ladder track to the parallel tracks

Gathering line at crossing angle

When the angle of inclination of the gathering line is the same as that of the turnout, it is said to be laid at the angle of crossing. In this situation, there is some gap between the back leg of the crossing of the turnout and the stock joint of the next turnout and a closure rail has to be used. The angle of the ladder track being equal to the angle of crossing, the two tracks intersect at the theoretical nose of crossing and no curve is introduced at the turnout crossing to connect the parallel tracks.

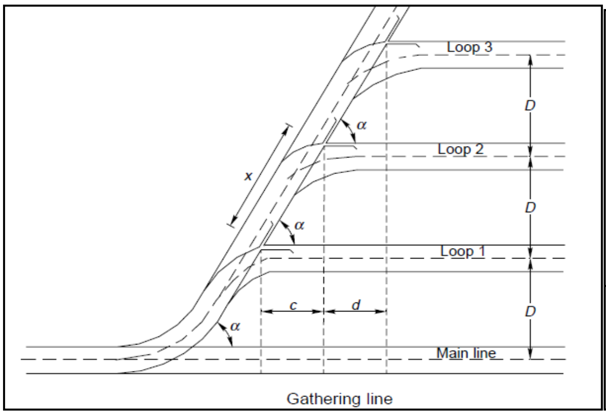
Gathering line at limiting angle

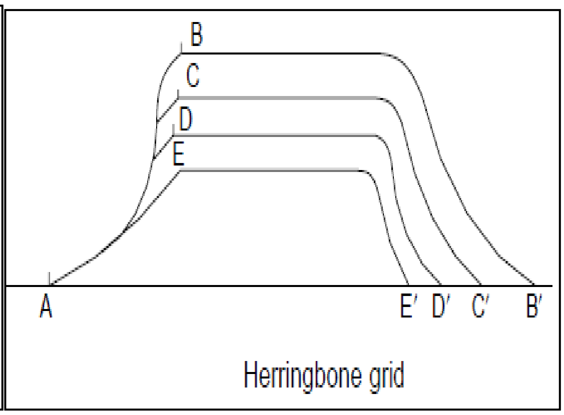
In this case the angle of the gathering line is greater than the crossing angle and a curve follows the back leg of the crossing. The back leg of the crossing is followed by the stock joint of the next turnout and no space is wasted. The limiting angle of the gathering line is given by following formula:

Sine of limiting angle = Space between two adjacent parallel tracks/Overall length of turnout

= D/x

Gathering lines can also be laid at 2α or 3α, i.e., at twice or thrice the crossing angle. Such gathering lines are generally found in marshalling yards and are known as *balloon layouts*. This layout of a marshalling yard based on the *Herringbone grid* is used when the various sidings of the marshalling yard are almost of equal length. This is not a very popular design.

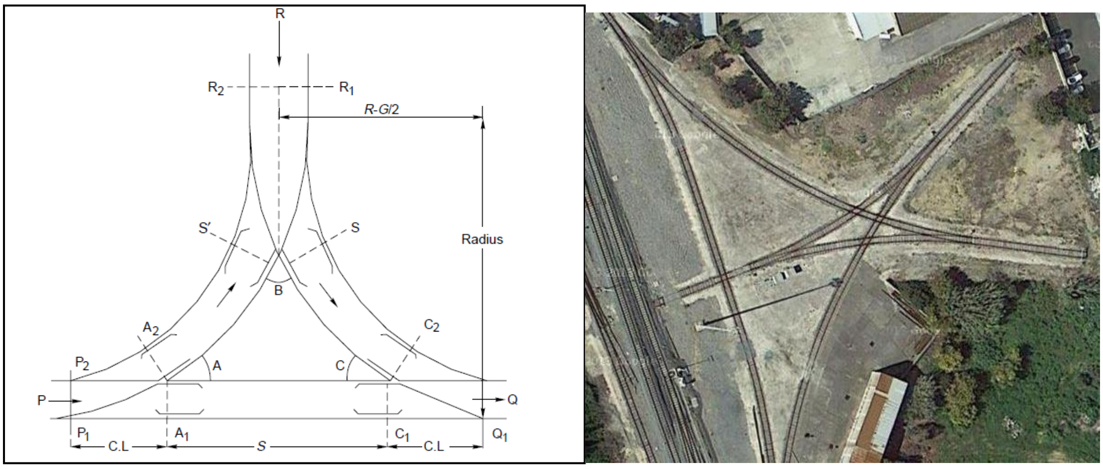




Gathering Line

Triangle

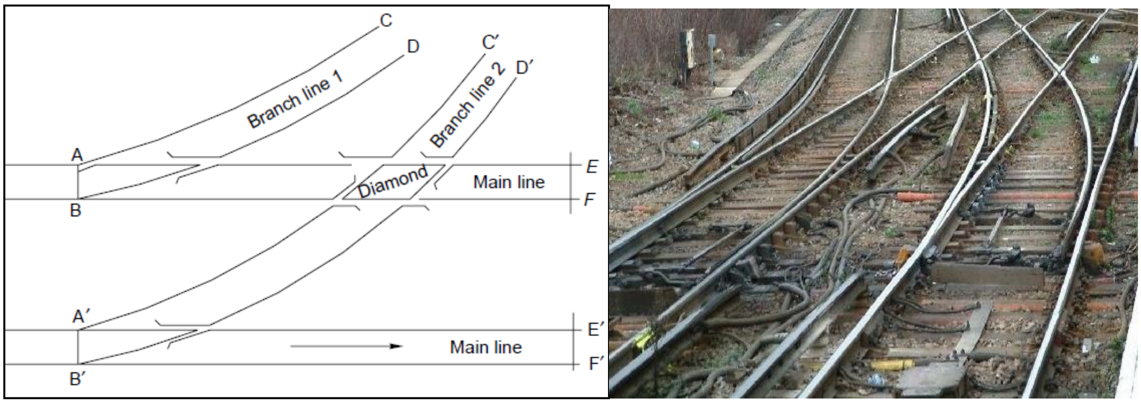
A triangle is mostly provided in terminal yards for changing the direction of an engine. Turntables are also used for this purpose, but are costly, cumbersome, and present a lot of problems in maintenance. Normally, a triangle is provided if enough land is available. A triangle consists of one symmetrical split at R and two turnouts at P and Q along with lead rails check rails, etc. To change the direction of an engine standing at P, it is first taken to R, then to Q, and then back to P. By following these movements, the direction of the engine gets changed. The concept of change of direction of the engine was more relevant in the case of steam locomotives and is not applicable to electric and diesel locomotives, which can be operated conveniently from both sides. With the phasing out of steam locomotive on Indian Railways, the triangle is mostly redundant.



Triangle

Double Junctions

A double junction is required when two or more main line tracks are running and other tracks are branching off from these main line tracks in the same direction. The layout of a double junction consists of ordinary turnouts with one or more diamond crossings depending upon the number of parallel tracks. Double junctions may occur either on straight or curved main lines and the branch lines may also be either single or double lines. These types of junctions are quite common in congested yards.



Double Junctions

SIGNALING AND INTERLOCKING

Introduction

The purpose of signaling and interlocking is primarily to control and regulate the movement of trains safely and efficiently. Signaling includes the use and working of signals, points, block instruments, and other allied equipment in a predetermined manner for the safe and efficient running of trains. Signaling enables the movement of trains to be controlled in such a way that the existing tracks are utilized to the maximum.

In fact in railway terminology signaling is a medium of communication between the station master or the controller sitting in a remote place in the office and the driver of the train.

Objectives of Signaling

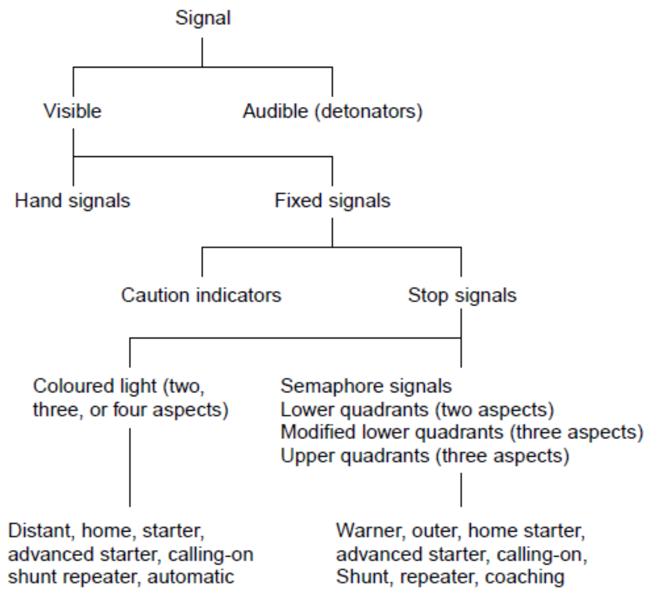
- To regulate the movement of trains so that they run safely at maximum permissible speeds.
- To maintain a safe distance between trains that is running on the same line in the same direction.
- To ensure the safety of two or more trains that has to cross or approach each other.
- To provide facilities for safe and efficient shunting.
- To regulate the arrival and departure of trains from the station yard.
- To guide the trains to run at restricted speeds during the maintenance and repair of tracks.
- To ensure the safety of the train when it comes in contact with road traffic at level crossings.

Classification of Signals

Based on different characteristics

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

DIFFERENT TYPES OF SIGNALS, THEIR WORKING AND LOCATION



1. **Audible Signals**

Audible signals such as detonators and fog signals are used in cloudy and foggy weather when hand or fixed signals are not visible. Their sound can immediately attract the attention of drivers. Detonators contain explosive material and are fixed to the rail by means of clips. In thick foggy weather, detonators are kept about 90 m ahead of a signal to indicate the presence of the signal to the drivers. Once the train passes over the detonators thereby causing them to explode, the driver becomes alert and keeps a lookout for the signal so that he/she can take the necessary action.

2. **Visible Signals**

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

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

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

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

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

STOP SIGNALS

a. ***Colored Light signals***
b. ***Semaphore signals***

a) COLORED LIGHT SIGNALS

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

  a) Two-aspect, namely, green and red

  b) Three-aspect, namely, green, yellow, and red

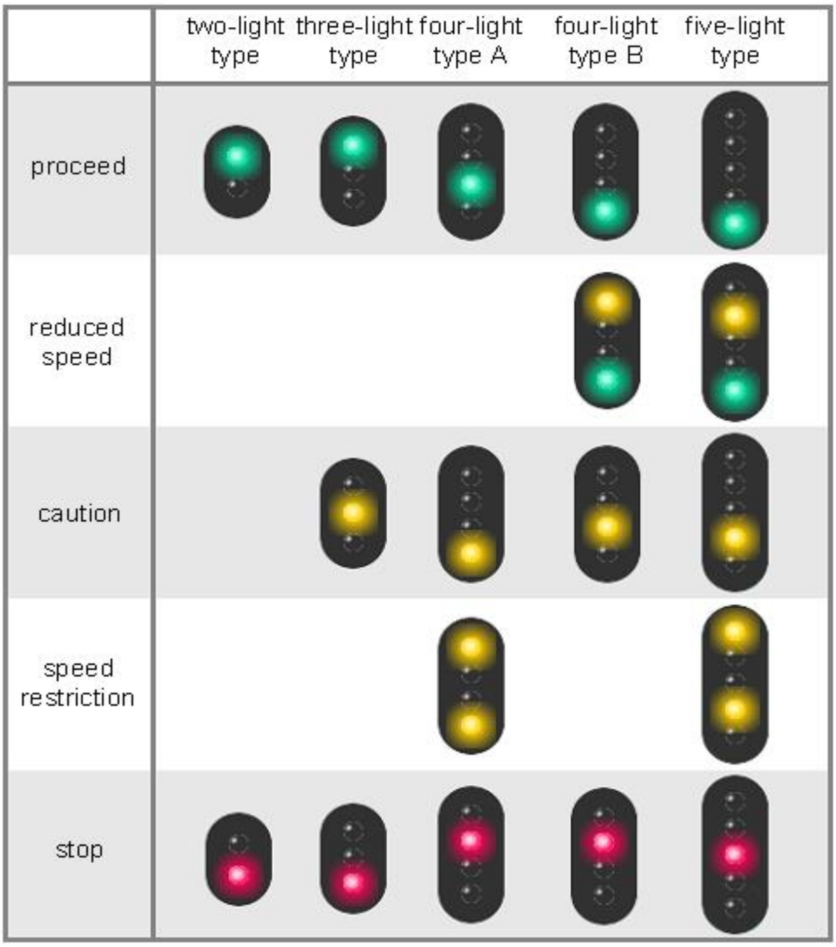
c) Four-aspect, namely, green, yellow (twice), and red.

- In India, mostly three-aspect or four-aspect colored light signaling is used. In the case of three-aspect signaling, green, yellow, and red lights are used. Green indicates ‘proceed’, yellow indicates ‘proceed with caution’, and red indicates ‘stop’.

Indications of coloured light signals	
Colour of signal	*Interpretation*
Red	Stop dead, danger ahead
Yellow	Pass the signal cautiously and be prepared to stop at the next signal
Two yellow lights displayed together	Pass the signal at full speed but be prepared to pass the next signal, which is likely to be yellow, at a cautious speed
Green	Pass the signal at full speed, next signal is also off

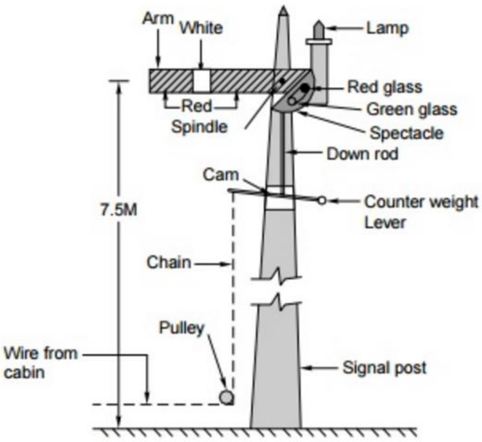
Colored Light signals

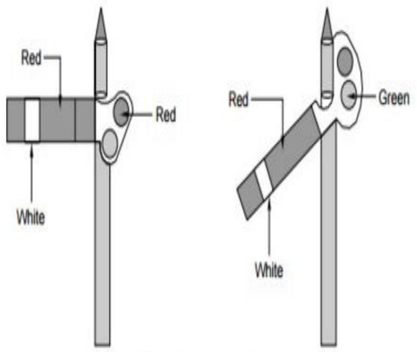
TWO ASPECTS	THREE ASPECTS	FOUR ASPECTS
		



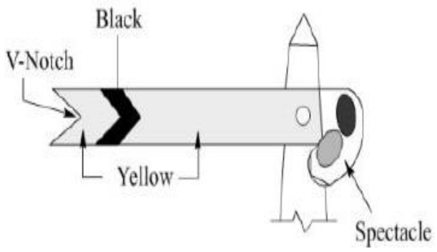
b) SEMAPHORE SIGNALS

- Consist of a vertical post on which a movable arm is pivoted at the top.
- Arm can be kept horizontal or it can be inclined at 45 degree to horizontal
- Outer end of arm is 2.45cm broader than that at post.
- Movable arm is controlled by means of levers and cables from the cabin.
- Spectacles of red and green or fixed in the arm
- These are fixed on the left hand side of track, with spectacles towards driver.
- Horizontal arm indicates “DANGER–STOP” and the inclined arm indicates “CLEAR–PROCEED”
- In the day time position of arm indicates the signal.
- During the night time light of lamp passing through spectacle gives the signal.





Positions of semaphore signals



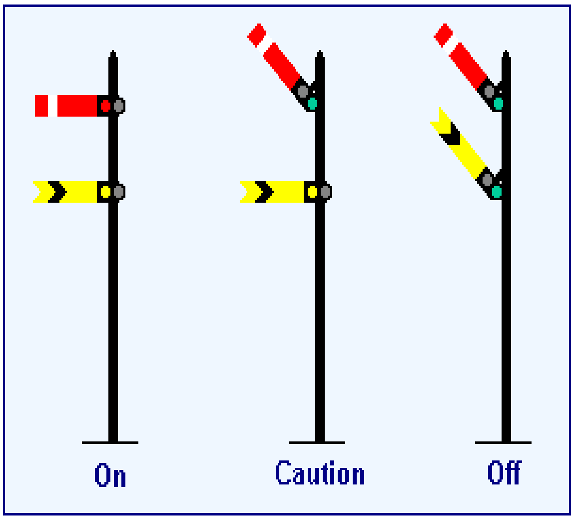
Indications give by a semaphore signal			
Position of signal	*Position of arm*	*Colour during night*	*Indication*
On	Horizontal	Red	Stop or danger
Off	Inclined 45° to 60° below horizontal	Green	Proceed or line is clear

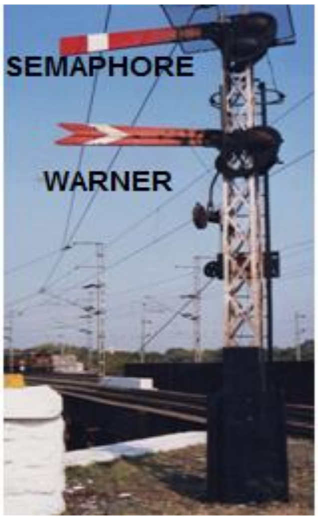
Position of Warner Arm or Distant Signal			
Position	*Day indication for Semaphore Signal*	*Night indication for Semaphore Signal*	*Aspect*
ON	Arm horizontal	Red light	Proceed with caution and be prepared to stop at next stop signal
CAUTION	Arm inclined 45° up	Yellow ligh	Proceed cautiously to pass the next stop signal at cautious speed
OFF	Arm inclined 90° up or 45° down	Green light	Proceed with full permissible speed; next stop signal is also green

Warner signal

A Warner signal is used only in two-aspect signaling (2LQ – Lower Quadrant, MLQ - Modified Lower Quadrant, 2CL – Color Light). This is similar to semaphore signal. The difference is it contains a fish tailed arm. These signals are placed ahead the semaphore signals to warn the driver before entering the railway station. Sometimes both Warner and semaphore signals are placed on the same pole at 2m distance between each on the pole. Warner signals are placed 540m away from the first stop signal. Its purpose is to warn of an approach to a stop signal further ahead, or to advise a driver of the condition of the block section being entered. Sometimes Warner signals are provided with yellow lights instead of red to distinguish them from semaphore signals during nights.

- **When the arm is horizontal – indicates signal ahead is stop**
- **Both horizontal – stop line not clear**
- **Semaphore lower, Warner horizontal – proceed with caution**
- **Both lowered – proceed on with confidence (this section and next section both are clear)**

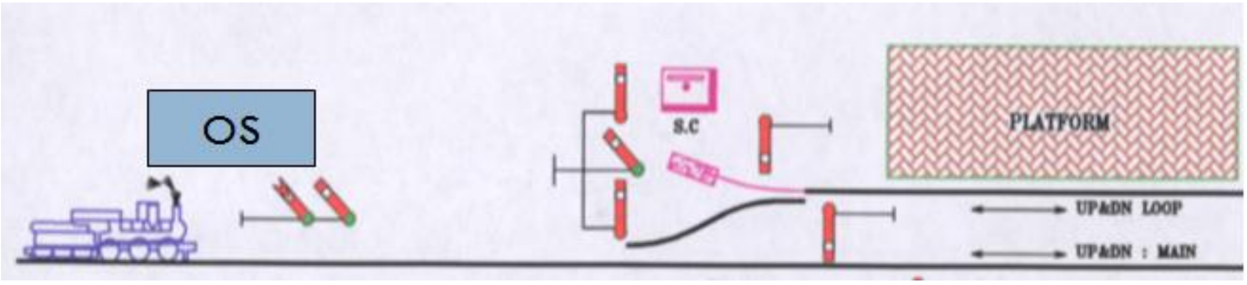




Outer signal

This is the Warner signal first seen by the driver. Trains moving at high speed require certain distance for stopping. Hence driver informed about the position in advance that platform is clear or not. This signal gives the position of stop signal ahead. As it is provided at some distance away from station it is also called as distant or outer or Warner signal.

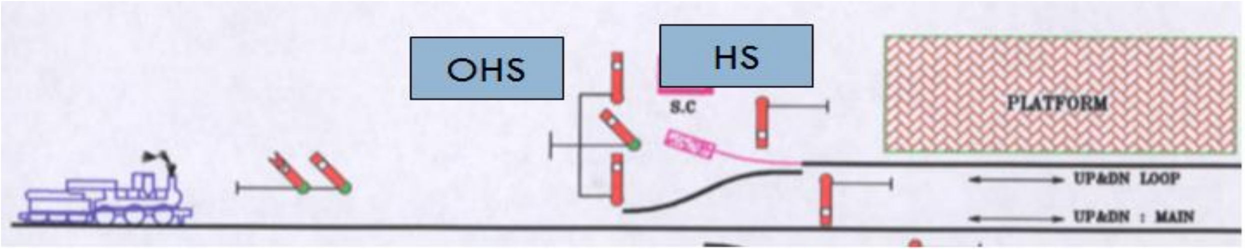
- **In horizontal or stop position it indicates that the driver must bring his train to halt within 90 m before outer signal and then proceed to the home signal with caution.**
- **In the inclined or proceed position it indicates that track and platform is clear and proceed normally without any danger.**



Horizontal or stop position *Inclined or proceed position*

Home signal

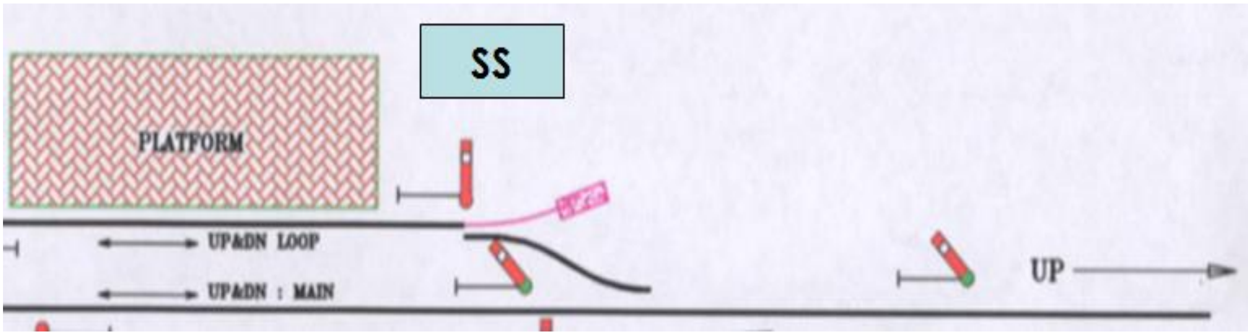
It is next signal after outer signal towards station. It is a simple semaphore signal and indicates whether platform is clear or not. This is the first stop signal on approach to a station without an outer home signal. It is not optional. After the outer signal towards station is a stop signal and exactly placed at the station limit is called home or stop signal. Its main function is to protect the stations. The permission to enter the platform is given by the operation of this signal. The maximum unprotected distance between the signal and the point, it is intended to protect is specified as 180 m due to its location at the door of station, it is called home signal.



Starter signal

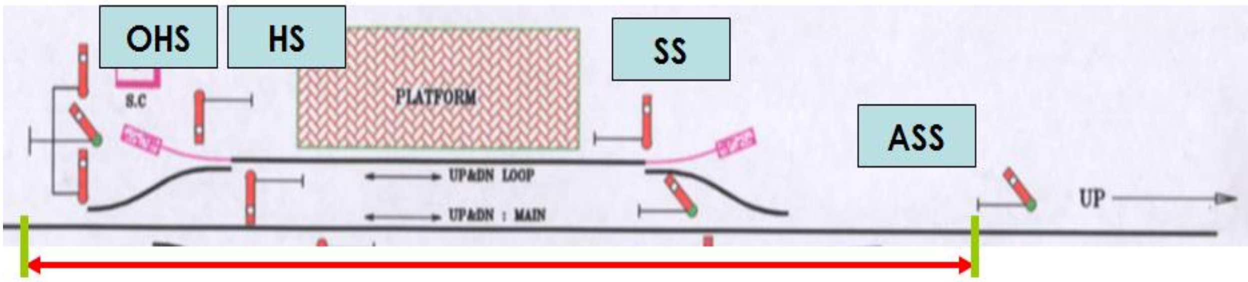
This signal is provided at the forward end of platform and controls the movement of the train as they leave the station. It gives permission to the train to leave the platform for next station. No train can leave the platform unless this signal is lowered, that is why it is called starter signal. A separate signal is provided for each line.

Normally the starter signal shows a 'Proceed' indication (green signal) to indicate that a train may leave the station, but in some cases an 'Attention' or 'Caution' indication (double yellow / yellow) may be used to allow the train to leave the station (and make the platform available for another train) but at a reduced speed.

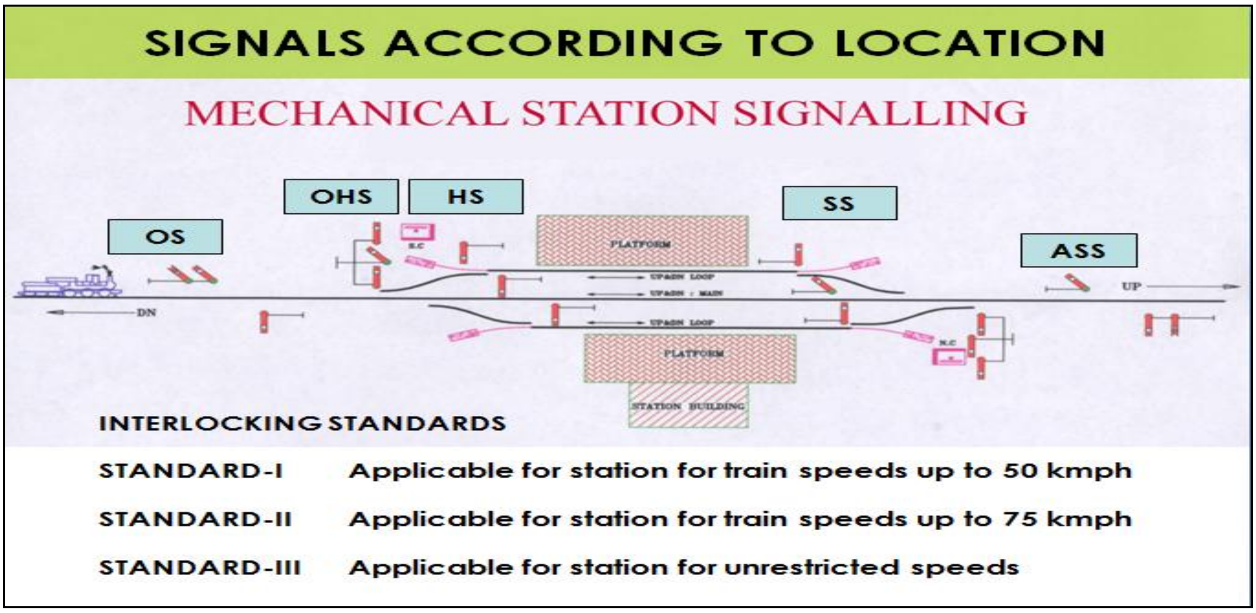


Advance starter signal

The limit of a station section lies between the home signal and the advance starter signal. The signal which allows the train to enter in block section is called advance starter signal. It is always placed beyond the outer most set of the point connections. These signals are placed about 180m beyond the last point or switches.



station section



ROUTING SIGNAL

When many branch lines diverge in different directions from the main line, it is very difficult to provide individual signal for each line at the divergent point.

In such situations various signals for main line and branch lines are fixed on the same vertical post. These signals are called routing signal. Generally signal for main line is kept higher than those for branch lines.

CONTROL SYSTEMS OF SIGNALS

The entire signaling system can be classified into two main categories.

A. Mechanical signaling system
B. Electrical signaling system

In addition to these two main categories of signaling systems, a solid-state signaling system is also in use. Each system of signaling comprises four main components.

1. Operated units such as signals and points
2. A transmission system such as single- or double-wire transmission or electrical transmission
3. Operating units such as levers and press buttons
4. Monitoring units such as detectors, treadle bars, and track circuiting

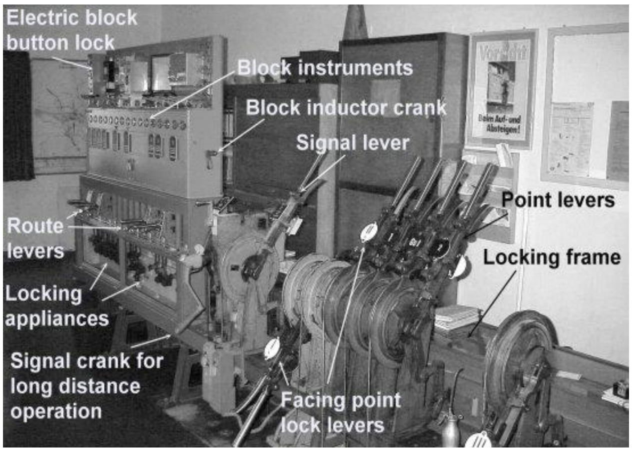
COMPARISON OF SIGNALING SYSTEM

Component	*Mechanical*	*Electrical*
Operated units		
Signals	Mechanically operated signals as per lower quadrant or upper quadrant signalling	Coloured light signals with two-aspect, three-aspect or four-aspect signalling
Points	Mechanically operated points; locking with the help of point locks, stretcher bars, and detectors	Electrically operated points (by converting the rotary movement of electric motors into linear push or pull); locking with the help of slides and solid rods.
Level crossing gates	Manually operated swing leaf gate or mechanically operated lifting barriers	Electrically operated lifting barriers
Transmission systems	Single- or double-wire transmission to the requisite points by means of rods or double wires	Electrical transmission through overhead wires or underground cables
Operating units	Hand levers with a range of 500 to 2000 m used in collaboration with single-wire or double-wire lever frames	Push buttons, rotary switches, or electrical signalling equipment
	Mechanical interlocking with tappets, etc.	Interlocking through electromagnetic switches known as relays or solid-state switching devices
Monitoring units	Monitoring of points with the help of detectors; monitoring of the passage of trains using a treadle, which is an electro-mechanical device	Monitoring with the help of direct current track circuits, alternating current track circuits, electronic track circuits, axle counters, etc.

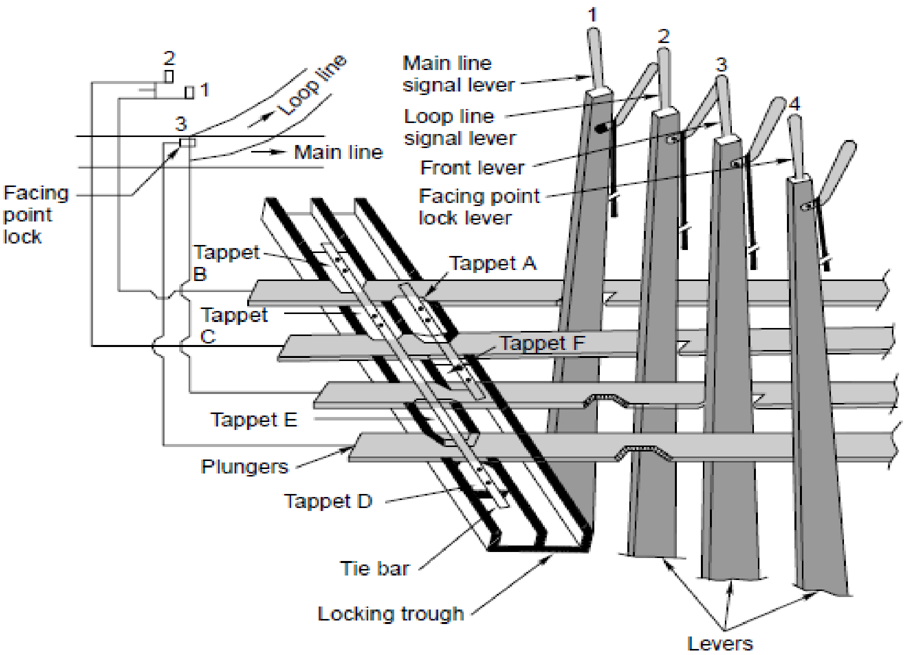
MECHANICAL METHOD OF INTERLOCKING SYSTEMS

Mechanical interlocking or interlocking on lever frames is an improved form of interlocking compared to key locking. It provides greater safety and requires less manpower for its operation. This method of interlocking is done using plungers and tie bars. The plungers are generally made of steel sections measuring 30 cm × 1.6 cm and have notches in them. The tie bars are placed at right angles to the plungers and are provided with suitably shaped and riveted pieces of cast iron or steel that fit exactly in the notches of the tappets.

The main components of an interlocking system are a locking frame, point fittings, signal fittings, and connecting devices for connecting the locking frame to the point and signal fittings. The locking frame consists of a number of levers, which work various points, point locks, signal levers, etc. The levers are arranged together in a row in a frame. Pulling a point lever operates the point to which it is connected through a steel rod. Similarly, pulling a signal lever changes the indication of the signal by pulling the wire connecting the lever and the signal. To each lever is attached a plunger which has suitably shaped notches to accommodate the locking tappets. The entire arrangement is provided in a locking trough where tappets are provided, which moves at right angles to the plungers.



When a lever is pulled, it causes the plunger to which it is connected to move. Due to *wedge action*, the tappet accommodated in the notch of the plunger is pushed out at right angles to the movement of the plunger. The motion is transmitted to all other tappets that are connected to this tappet through a tie bar. As a result of this motion, the other tappets either get pushed into or out of the respective notches of the other plunger depending upon the type of interlocking provided. In case the other tappet is free but slips inside the notch of the other plunger, it locks the lever connected to this plunger. In consequence, the other lever gets locked in that position and cannot be operated. However, if the tappet was earlier positioned in the notch of the plunger, thereby locking the lever, and is now out of the notch, the other lever becomes free to be operated.



Interlocking of points and signals of a two-line railway station

TRACK CIRCUITING

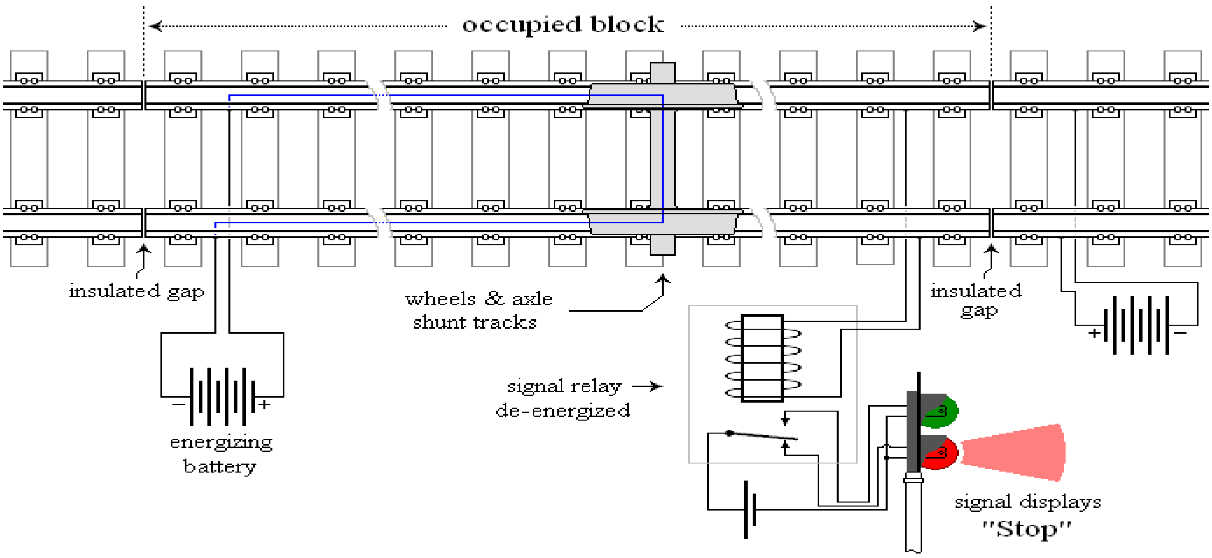
- Track circuit is simple electrical device used to detect the Presence/Absence of train on the rails.
- Track circuit is the one of the primary input for a signal interlocking plant.
- The signal cannot be green while there is another train on track segment ahead.

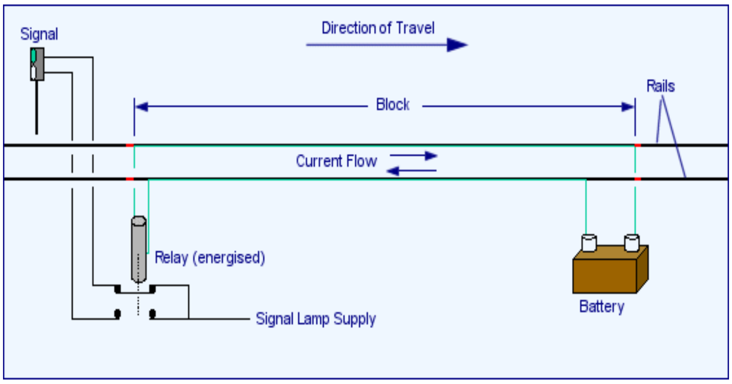
Components of track circuit

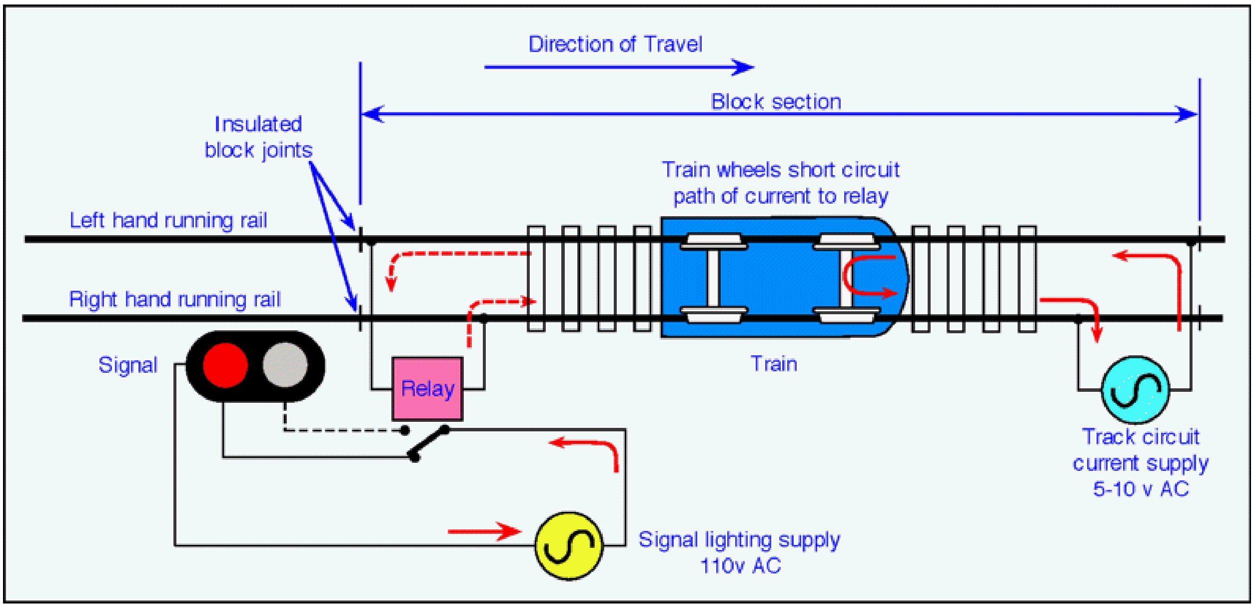
a. Battery.
b. Track Relay.
c. Adjustable resistance.
d. Insulated rail joints.

Working of circuit

- The portion of the Track which is to be Track circuited is first provided with wooden or RCC sleepers and then the rails are insulated from the rest of the Track by the provision of Insulated rail joints.
- At one end of the Track circuit feed is connected and at other end track relay is connected.
- When the track portion is not occupied by trains, the fed is available for track relay and the relay is in energized condition.
- When a train occupies the track circuit portion, the axel & wheels shunt the track much of the circuit current is passed through the wheels due to less resistive path and very less current is available for track relay, which is not sufficient enough to pick up the relay




Signal
Direction of Travel
Rails
Block
Current Flow
Relay (energised)
Battery
Signal Lamp Supply


Direction of Travel
Block section
Insulated
block joints
Train wheels short circuit
path of current to relay
Left hand running rail
Right hand running rail
Signal
Relay
Train
Track circuit
current supply
5-10 v AC
Signal lighting supply
110v AC

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – IV – Railways, Airport and Harbour Engineering – SCIA1701

IV. Airport Planning and Design

Introduction - classification of airports - Factors influencing the selection of new airport site and ICAO stipulations - layout characteristics, socio-economic characteristics of the Catchment area - components of Airport Runway Orientation: Wind Rose Diagram - Problem on Basic and Actual runway length - Aircraft Parking system - Drainage - Airport Zoning - Runway and Taxiway Markings and lighting - Design standards and planning of Airport as per Indian condition.

<u>INTRODUCTION</u>

The planning of an airport is such a difficult process that the analysis of one activity without regard to the effect on other activities will not provide acceptable solutions. An airport includes a wide range of activities which have different and often contradictory requirements. Yet they are co-dependent so that a single activity may limit the capacity of the whole complex. In the past airport master plans were developed on the basis of local aviation needs. In more recent times these plans have been integrated into an airport system plan which assessed not only the needs at a specific airport site but also the overall needs of the system of airports which service an area, region, state, or country. If future airport planning efforts are to be successful, they must be founded on guidelines established on the basis of comprehensive airport system and master plans.

Role of Air transportation

- Improves accessibility to otherwise inaccessible areas
- Provides continuous connectivity over land and water (no change of equipment)
- Saves productive time, spent on journey
- Increase the demand of specialized technical skill workforce
- Adds to the foreign reserve through tourism
- Speed: Modern jet can travel at 1000 km/h
- Promotion of trade and commerce
- Military use
- Relief and rescue operations
- Aerial photography
- Agricultural spraying
- Safety - safe mode of transport.

Disadvantages of air transport

- Heavy funds are required, not only initially but also during operation
- Operations are highly dependent up on weather conditions
- It needs highly sophisticated machinery
- Adds to the outward flow of foreign reserve
- Noise pollution
- Safety provisions are not adequate
- Specific demarcation of flight paths and territories is essential.
- High energy consumption

CLASSIFICATION OF AIRPORTS

The airports are classified by various agencies, the most popular one being by ***International Civil Aviation Organization*** (ICAO). The airport classification aims at achieving the uniformity in the design standards. The classification by ICAO is based in the following two ways

- Based on runway length, width of runway pavement and maximum longitudinal grade.
- Based on single isolated wheel load and tyre pressure.

ICAO Airport Classification

Airport Type	Basic Runway Length (m)		Width of Runway Pavement (m)	Maximum longitudinal grade (%)
	Maximum	Minimum		
A	Over 2100	2100	45	1.5
B	2099	1500	45	1.5
C	1499	900	30	1.5
D	899	750	22.5	2.0
E	749	600	18	2.0

Classification of Airport in India

1. *International Airports in India*

   The following airports link the major Indian cities to the international cities:

   a. Amritsar International Airport
   b. Indira Gandhi International Airport, New Delhi
   c. Lokpriya Gopinath Bordolio International Airport, Guwahati
   d. Sardar Vallabhbhai Patel International Airport, Ahmedabad
   e. Netaji Subhash Chandra Bose International Airport, Kolkata
   f. Chhatrapati Shivaji International Airport, Mumbai
   g. Hyderabad Airport
   h. Goa Airport
   i. Bangalore International Airport
   j. Cochin International Airport
   k. Chennai International Airport
   l. Trivandrum International Airport

2. *Domestic Airports in India*

   All the Indian airports come under this category.

3. *Custom Airports in India*

   Custom Airports provide immigration and customs facilities for the international tourists. They also operate cargo charter flights. The custom airports in India are located at:

      a. Bangalore
      b. Hyderabad
      c. Ahmedabad
      d. Calicut
      e. Cochin
      f. Goa
      g. Varanasi
      h. Patna
      i. Agra
      j. Jaipur
      k. Amritsar
      l. Tiruchirapally

4. *Model Airports in India*

   Indian Model Airports are the domestic airports with following features:

   - Minimum 7500 feet length of runway
   - Sufficient terminal capacity for handling aircraft of Airbus 320 type If required, can also handle limited international traffic

   The model airports in India are located in:

   a. Lucknow
   b. Bhubaneshwar
   c. Guwahati
   d. Nagpur
   e. Vadodara
   f. Coimbatore
   g. Imphal
   h. Indore

5. *Civil Enclaves in Indian Defense Airports*

   28 civil enclaves are included in the Defense airfields of India.

FACTORS INFLUENCING THE SELECTION OF NEW AIRPORT SITE AND ICAO STIPULATIONS

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

1. Regional Plan
2. Airport Use
3. Proximity to Other Airport
4. Ground Accessibility
5. Topography
6. Obstructions
7. Visibility
8. Wind

9. Noise Nuisance
10. Grading, Drainage and Soil Characteristics
11. Future Development
12. Availability of Utilities from Town
13. Economic Consideration

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 that is whether for civilian or for military operations. However during the emergency civilian airports are taken over by the defense. Therefore the airport site selected should be such that it provides natural protection to the area from air roads. This consideration is of prime importance for the airfields to be located in combat zones

Proximity to other airport: 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.

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 especially for short haul operations.

Topography: this includes natural features like ground contours trees streams etc. A raised ground a hill top is usually considered to be an ideal site for an airport.

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 loss altitude.

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 blows minimum in a valley.

Wind: runway is so oriented that landing and takeoff is done by heading into the wind should be collected over a minimum period of about five years.

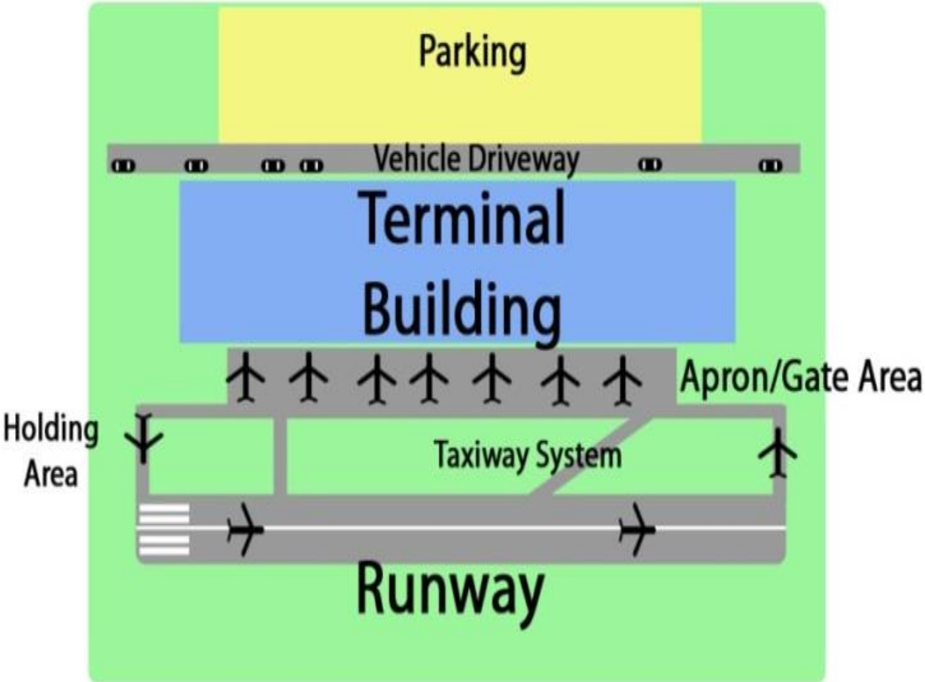
Noise nuisance: the extent of noise nuisance depends upon the climb out path of aircraft type of engine propulsion and the gross weight of aircraft. The problem becomes more acute with jet engine aircrafts. Therefore the site should be so selected that the landing and takeoff paths of the aircrafts pass over the land which is free from residential or industrial developments.

Grading, drainage and soil characteristics: grading and drainage play an important role in the construction and maintenance of airport which in turn influences the site selection. The original ground profile of a site together with any grading operations determines the shape of an airport area and the general pattern of the drainage system. The possibility of floods at the valley sites should be investigated. Sites with high water tables which may require costly subsoil drainage should be avoided.

Future development: considering that the air traffic volume will continue to increase in future more member of runways may have to be provided for an increased traffic.

LAYOUT CHARACTERISTICS AND SOCIO-ECONOMIC CHARACTERISTICS OF THE CATCHMENT AREA

COMPONENTS OF AIRPORT



The **main components of airport are**

1. Landing Area of Airport

It is the airport components used for landing and takeoff operations of an aircraft. Landing Area includes ***Runways*** and ***taxiways***.

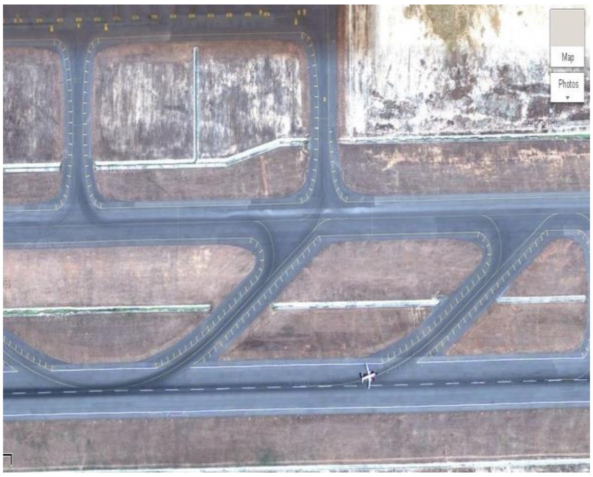
Landing area is the component of airport used for landing and takeoff operations of an aircraft. Landing area includes,

a. Runways
b. Taxiways

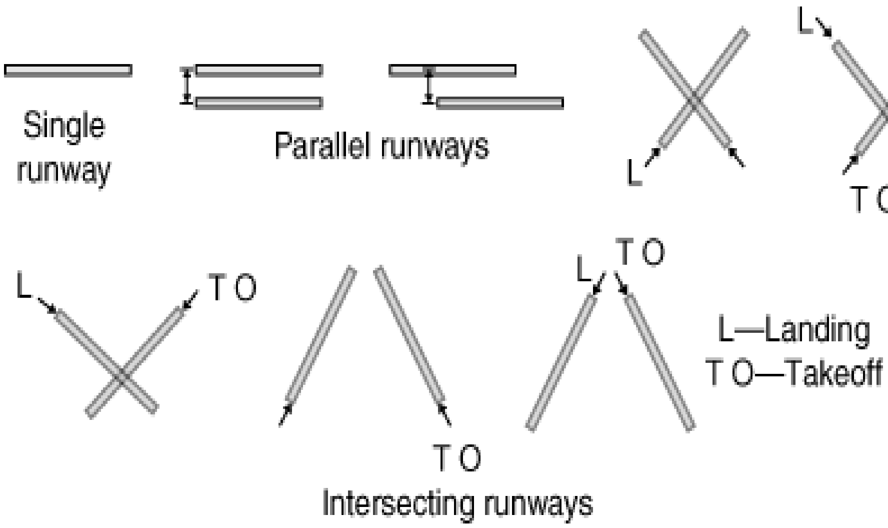
a. Runways

It is the most important part of an airport in the form of paved, long and narrow rectangular strip which actually used for landing and takeoff operations. It has turfed (grassy) shoulders on both sides. The width of runway and area of shoulders is called the landing strip. The runway is located in the center of landing strip. The length of landing strip is somewhat larger than the runway strip in order to accommodate the stop way to stop the aircraft in case of abandoned takeoff.

The length and width of runway should be sufficient to accommodate the aircraft which is likely to be served by it. The length of runway should be sufficient to accelerate the aircraft to the point of takeoff and should be enough such that the aircraft clearing the threshold of runway by 15m should be brought to stop with in the 60% of available runway length. The length of runway depends on various meteorological and topographical conditions. Transverse gradients should not be less than 0.5% but should always be greater than 0.5%.



Runway *Taxiway*



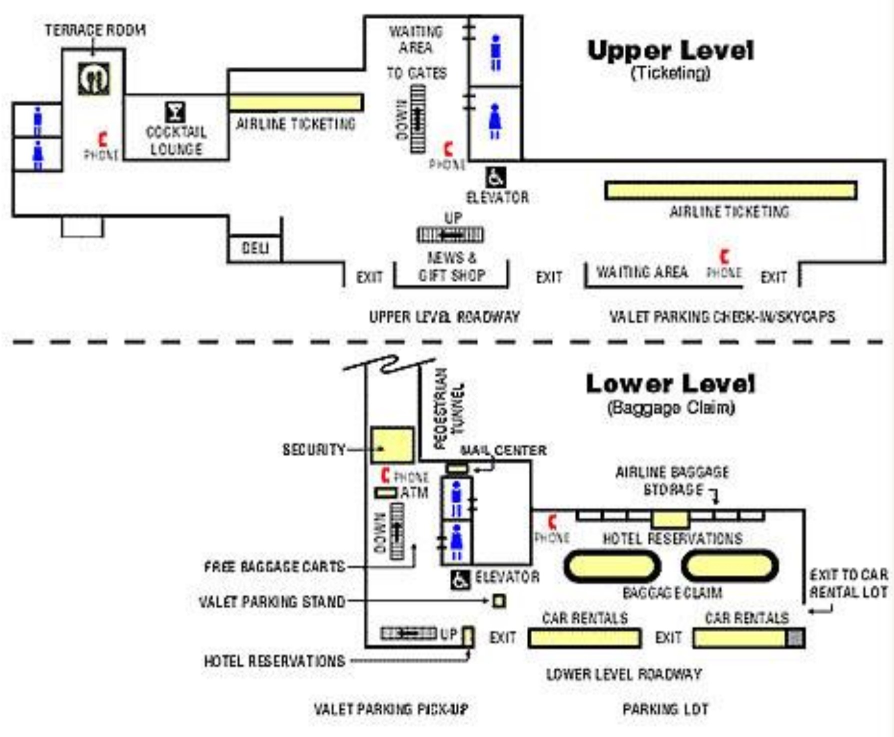
b. Taxiways

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

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

2. Terminal Area

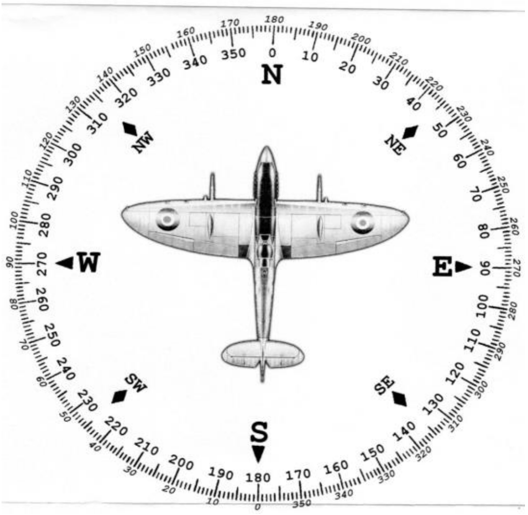
The transition of passengers and goods from ground to air takes place in the terminal area. Various methods are used to accommodate and transfer the public and its goods arriving either by ground or by air. The degree of development in the terminal area depends up on volume of airport, operations, type of air traffic using airport, number of passengers and the airport employees to be served and the manner in which they are served and accommodated. Terminal area consists of the following parts ***Terminal building***, ***Apron***, ***Automobile Parking Area***, ***Hangers***.



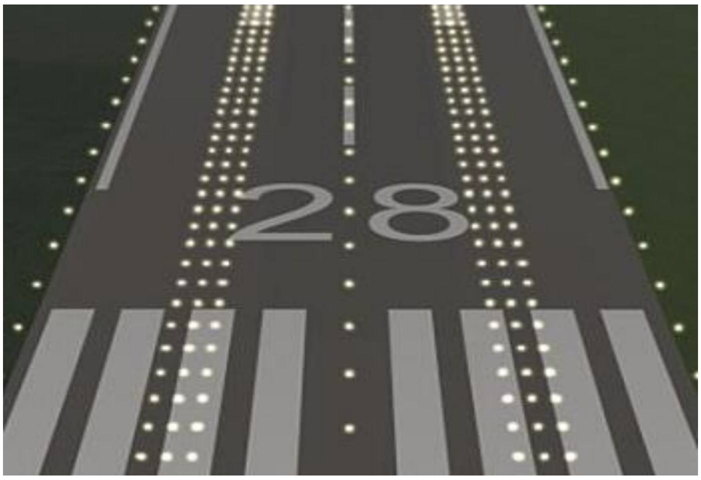
Terminal building

RUNWAY ORIENTATION

According to the International Civil Aviation Organization (ICAO) a runway is a "defined rectangular area on a land aerodrome prepared for the landing and takeoff of aircraft". The orientation of the runway is an important consideration in airport planning and design. The correct runway orientation maximizes the possible use of the runway throughout the year accounting for a wide variety of wind conditions. FAA and ICAO regulations establish rules about runway orientation and their expected coverage Runway Location Considerations. FAA mandates identification standards for airport layout that is meant to assist pilots in easily recognizing runways. Ideally, all aircraft operations on a runway should be conducted against the wind. Unfortunately, wind conditions vary from hour to hour thus requiring a careful examination of prevailing wind conditions at the airport site. The challenge for the designer is to accommodate all of the aircraft using the facility in reliable and reasonable manner. In navigation, all measurement of direction is performed by using the numbers of a compass. A compass is a 360° circle where 360° is north, 90° is east, 180° is south, and 270° is west, as shown in figure.



Runways are laid out according to the numbers *on a compass*. A runway compass direction is indicated by a large number painted at the end of each runway. Preceding that number are 8 white stripes.



Following that number by 500 feet is the "touch down zone" which is identified by 6 white stripes.

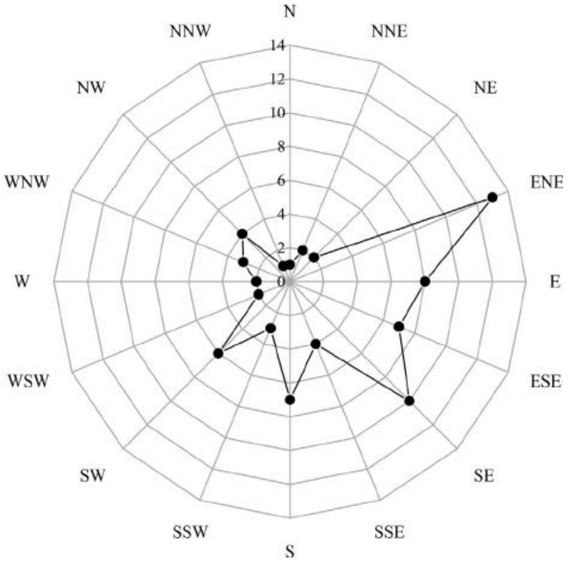
WIND ROSE DIAGRAM

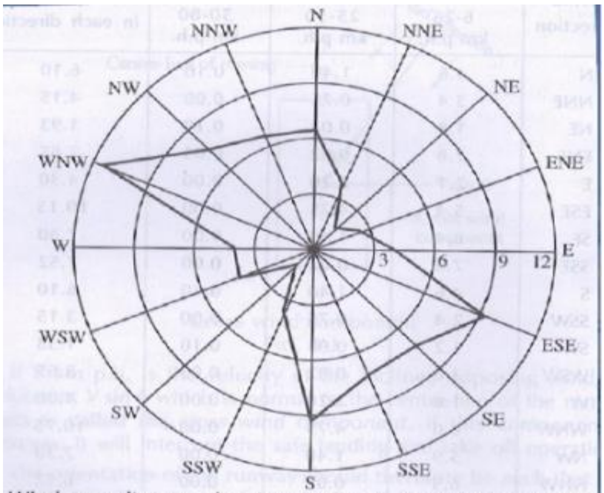
The wind data direction duration and intensity are graphically represented by a diagram called wind rose. The wind data should usually be collected for a period of at least 5 years and preferably of 10 years so as to obtain an average data with sufficient accuracy.

Wind rose diagrams can be plotted in two types

- Showing direction and duration of wind
- Showing direction duration and intensity of wind.

Type – I: This type of wind rose is illustrated in fig. The radial lines indicate the wind direction and each circle represents the duration of wind. The values are plotted along the north direction in fig similarly other values are also plotted along the respective directions. All plotted points are then joined by straight lines.

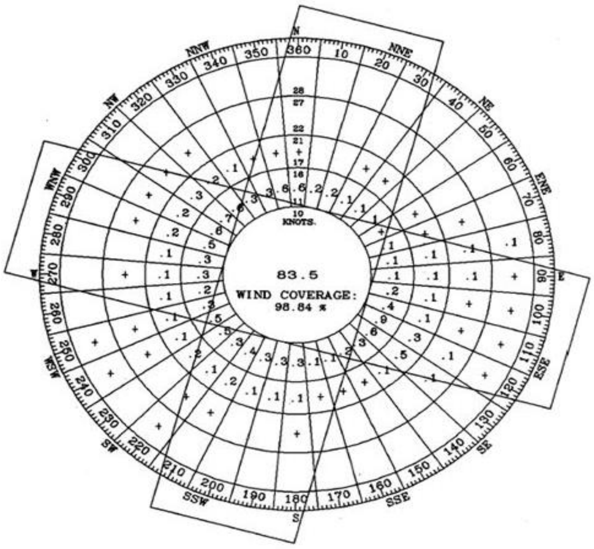


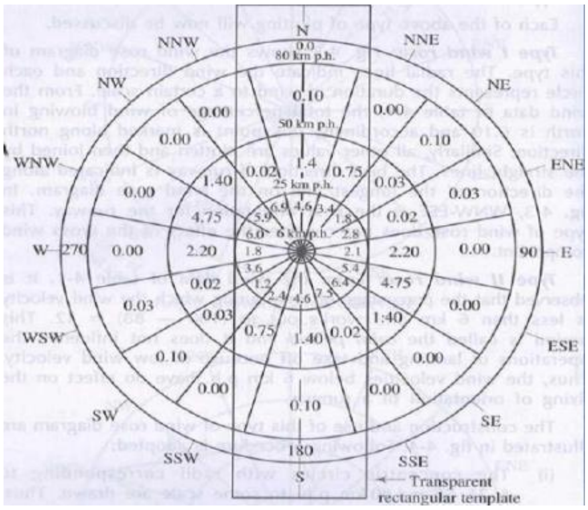


Wind rose diagram showing direction and duration of wind

The best direction of runway is usually along the direction of the longest lone on wind rose diagram. If deviation of wind direction up to 22.5º + 11.25ºfrom their direction of runway is thus along NS direction of landing and takeoff is permissible the percentage of time in a year during which runway can safely be used for landing and takeoff will be obtained by summing the percentages of time along NNW, N, NNE, SSE, S and SSW directions. This comes to 57.6 percent. The total percentage of the time therefore comes to 57.0 + 13.5 = 70.5. This type of wind rose does not account for the effect of cross wind component.

Type – II: This type of wind rose is illustrated in fig. the wind data as in the previous type 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 a particular intensity blows from the respective direction. The procedure for determining the orientation of runway from this type of wind rose is described below.





Draw three equally spaced parallel lines on a transparent paper strip in such a way that the distance between the two nearby 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 the permissible cross wind component is 25kmph. 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.

PROBLEM ON BASIC AND ACTUAL RUNWAY LENGTH

Basic Runway Length:

The length is calculated under the following conditions:

- No wind blowing on the runway.
- Aircraft is loaded with full loading capacity.
- Airport is provided at the sea level
- No wind is blowing on the way to the destination
- The runway is leveled and it is provided with zero effective gradient.
- The standard temperature is 15 degrees centigrade at the airport.

Factor affecting basic runway length

- Aircraft Performance Characteristics.
- Landing & Take–Off Gross Weights of the Aircraft.
- Airport Elevation.
- Maximum Temperature.
- Runway Gradient.
- Runway Surface Condition.

It is the length of runway under the following assumed conditions at the aircraft

1. Airport altitude is at sea level
2. Temperature at the airport is standard (15°C)

3. Runway is leveled in the longitudinal direction.
4. No wind is blowing on runway.
5. Aircraft is loaded to its full loading capacity.
6. There is no wind blowing enroute to the destination.
7. Enroute temperature is standard.

<u>Corrections for Elevation, Temperature and Gradient</u>

(a) Correction of Elevation: Basic runway length is increased at the rate of 7% per 300 m rise in elevation above the mean sea level.

(b) Correction for Temperature

Airport reference temperature $= T_a + \frac{T_m - T_a}{3}$

Where, T_a = monthly mean of average daily temperature

T_m = monthly mean of the max daily temperature for the same month of the year.

Total correction for elevation plus temperature represents the 35% of basic runway length.

(c) 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.
- After having been corrected for elevation and temperature should be further increased at the rate of 20% for every 1% 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.

Actual Runway Length

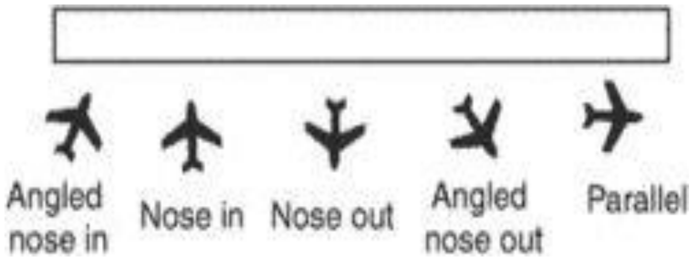
The length of a full-width usable runway from end to end, or full-strength pavement where such runways are paved is the actual length of the runway

<u>AIRCRAFT PARKING SYSTEM</u>

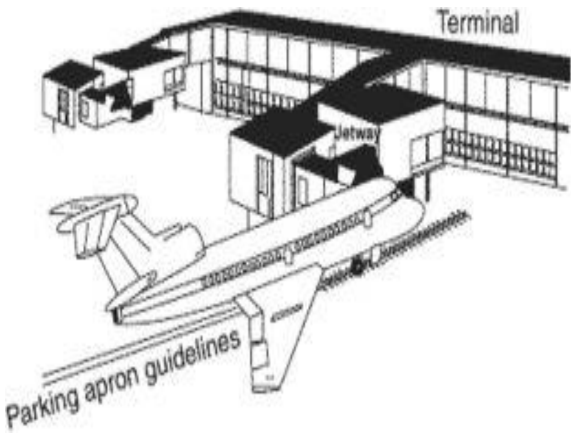
The type of parking used at the gates affects the gate size because the area required to maneuver (a planned movement of an aircraft) in and out of a gate varies depending on the way the aircraft is parked.

Types of Aircraft parking

1. Nose – in parking
2. Angled nose – in parking
3. Nose – out parking
4. Angled nose – out parking
5. Parallel parking



1. **Nose In parking -**The aircraft is parked at right angles to the terminal building with its nose as close to the building as permissible. The aircraft moves into the parking position under its own power and in order to leave the gate, the aircraft has to be towed out a sufficient distance to allow it to proceed under its own power.



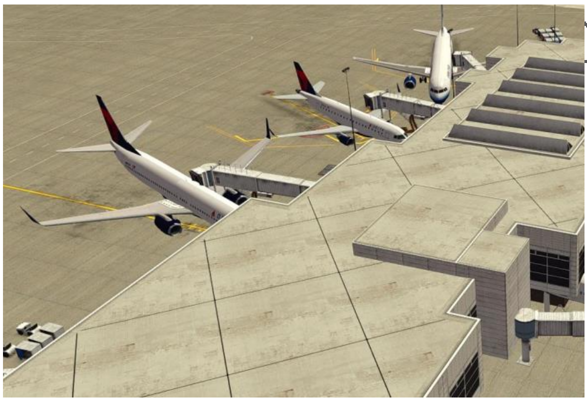
Advantages

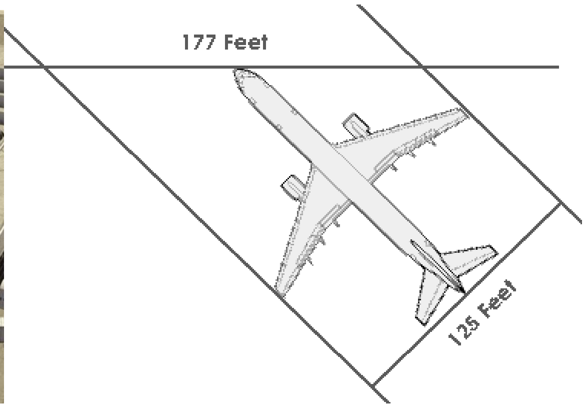
- Causes lower noise levels as there is no powered turning movement near the terminal building.
- It facilitates passenger loading as the nose is near the terminal building.
- Requires smallest gate area for a given aircraft.
- Sends no jet blast towards the terminal building.

Disadvantages

- Large power is required while moving the loaded aircraft out of the gate position.
- The nose is too near the terminal building for effectively using the rear doors for passenger loading.

2. **Angled Nose In parking -** This is similar to the nose – in parking except that the aircraft is not parked perpendicular to the terminal building.





Advantage

- ➢ This arrangement allows the aircraft to move in and out of the gate under its own power.

Disadvantage

- ➢ But it however requires a larger gate area than the nose in configuration and causes a higher noise level.

3. **Nose Out Parking -** The aircraft is parked at right angle to the terminal building with its tail as close to the building as permissible.

Advantage

- ➢ Permits effective use of the rare door.
- ➢ Requires less power while maneuvering the loaded aircraft out of the gate.

4. **Angled Nose Out Parking –** This is similar to the nose–out parking except that the aircraft is not parked perpendicular to the terminal building.

Advantage

- ➢ This arrangement allows the aircraft to move in and out of the gate positions without towing.

Disadvantage

- ➢ The hot jet blast and the noise are pointed towards the terminal building when the aircraft starts its taxing maneuver.

5. **Parallel Parking - It** is the easiest to achieve from the stand point of aircraft maneuvering.

Advantage

- ➢ Both front and rear doors can be used for loading and unloading of the passengers.

Disadvantage

- ➢ The hot blast and the noise are directed towards the adjacent gate position.
- ➢ It requires relatively long loading bridge.
- ➢ It requires a larger gate position area especially along the terminal building frontage.

AIRPORT DRAINAGE

An adequate drainage system for the removal of surface and subsurface water is vital for the safety of aircraft and for the long service life of the pavements. Improper drainage results in the formation of puddles on the pavement surface which can be hazardous to aircraft taking off and landing poor drainage can also results in the early deterioration of pavements.

Purpose of drainage

The functions of an airport drainage system are as follows;

- Intercepting and diversion of surface and ground water flow originating from lands adjacent to the airport.
- Removal of surface run off from the airport
- Removal of subsurface flow from the airport

Design storm for surface run off

Federal aviation administration recommends that for civil airports the drainage system be designed for a storm whose probability of occurrence is once in 5 years. The designs should, however be checked with a storm of lesser frequency (10 to 15 years). Drainage system for military airfields is based on a 2-years storm frequency. Rainfall intensity is expressed in inches per hour for various durations of a particular storm. The FAA adopts the following formula for the calculation of amount of runoff.

$$Q = CIA$$

Q = Runoff from the drainage basin (ft/sec)

C = ratio of runoff to rainfall (coefficient of runoff)

I = Rainfall intensity (inch /hour)

A = Drainage area in acres

For drainage basins consisting of several types of surfaces with different infiltration characteristics, the weighted run off coefficient should be computed as

$$C = \frac{A_1C_1+A_2C_2+A_3C_3}{A_1+A_2+A_3}$$

Having calculated the discharge to be handled, the pipes diameter is determined. Pipes used are of perforated metal, concrete on vitrified clay. Pipes are of usually 6” diameter wth a minimum recommended slope of 0.15%. a minimum thickness of 6” of filter material should surround the drain and filter material must be many times more pervious than the protected soil. For cleaning and inspection, manholes and risers are often installed along the drains. The crops of engineers recommend that manhole be placed at intervals not more than 1000 ft with one riser midway between the manholes.

Some time one combined drain is provided both for surface and subsurface drainage (combined system).

Surface drainage

Water from a discharge area is collected into the storm drain by means of inlets. The inlets structures consists of a concrete box, whose top is covered with a grating made of cast iron, cast steel or reinforced concrete a cover is designed to takes aircraft wheel loads. The inlets are spaced from 200 – 400 ft. Support locations of inlets depend on the configuration of the airport and on the grading plan.

Normally drains are placed near the edge of the runway pavement or at the toe of the slope of the graded area. The grades of the storm drain should be such as to maintain a minimum velocity of 2.5 ft/sec self cleaning velocity. The diameter of surface drains should not be less than 12”. The design should be such that entire quantity of surface run off should be removed in 1 to 2 hours following the rain storm.

Ponding

If the airport area is subjected to high rainfall intensities and calculations gives very large diameter of drains required to remove water from the land area. So ponding of water is done to accumulate water for some time and then allow it to enter the drains, thus reducing size of drains. Water is collected in catch basin and carried away by storm sewer.

Sub surface drainage

Functions of subsurface drainage are to

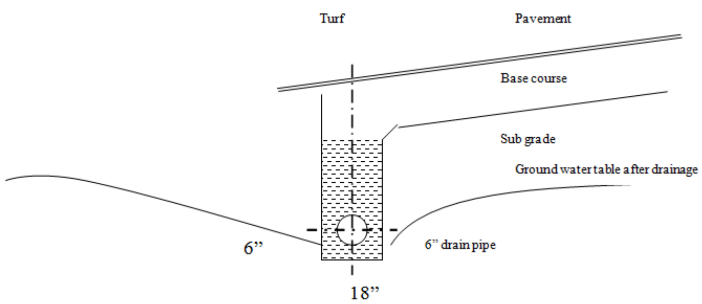
- Remove water from a base course
- Remove water from the sub grade beneath a pavement and
- Intercept, collect and remove water flowing from springs and previous strata.

Base drainage is usually required;

- Where frost action occurs in the sub-grade beneath a pavement
- Where the ground water is expected to rise to the level of base course.
- Where the pavement is subjected to frequent inundation and the sub-grade is highly impervious and sub surface waters from adjacent areas are seeping towards the airport pavements.

Methods for draining sub-surface water

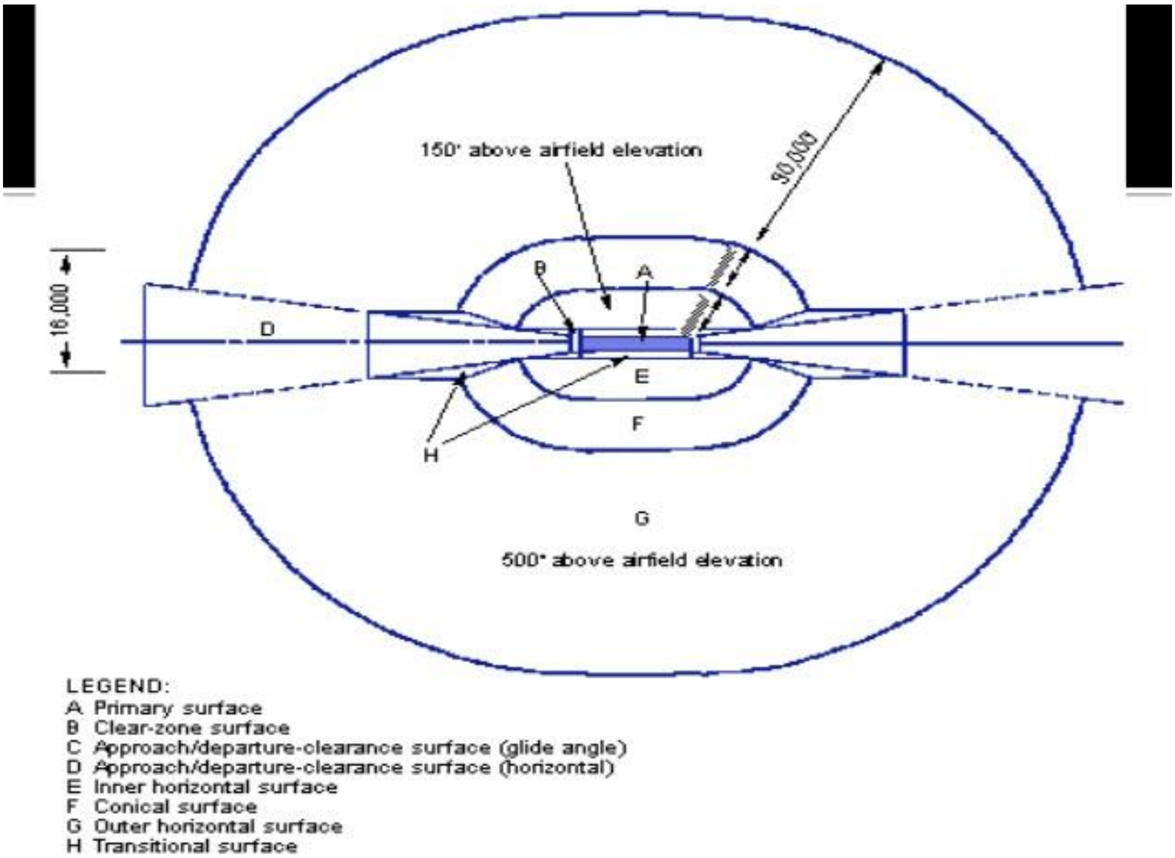
Base course are usually drained by installing sub-surface drains adjacent to and parallel to the edge of pavement. The pervious material in the trench should extend to the bottom of base course and center line of the drain pipe should be placed a minimum of 1 ft below the bottom of the base course. Sub grade is drained by pipes installed along the edge of the pavement and the center line of the drain should be placed at edge.

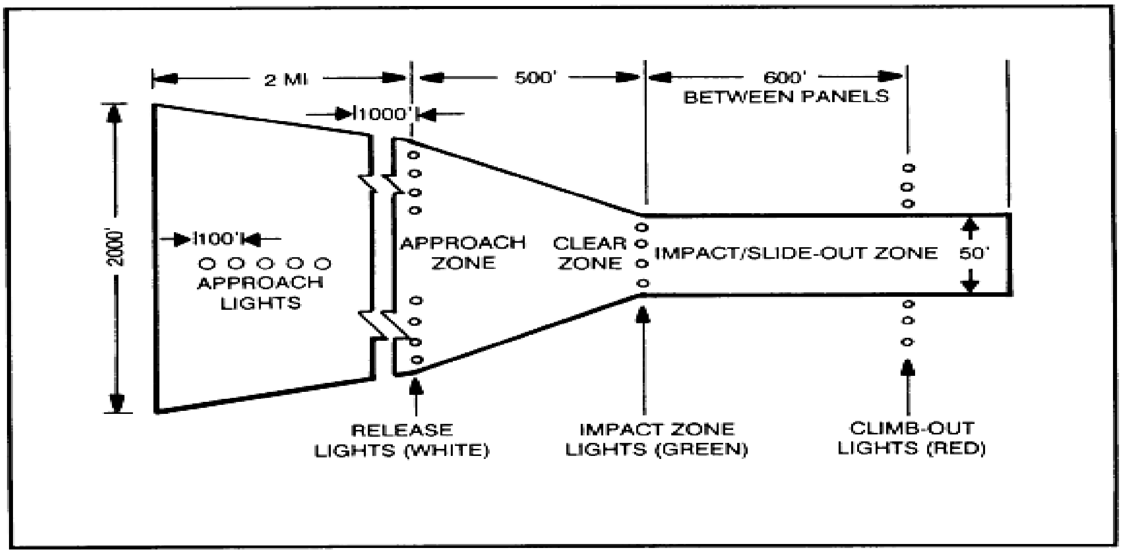


AIRPORT ZONING

Clear Zone

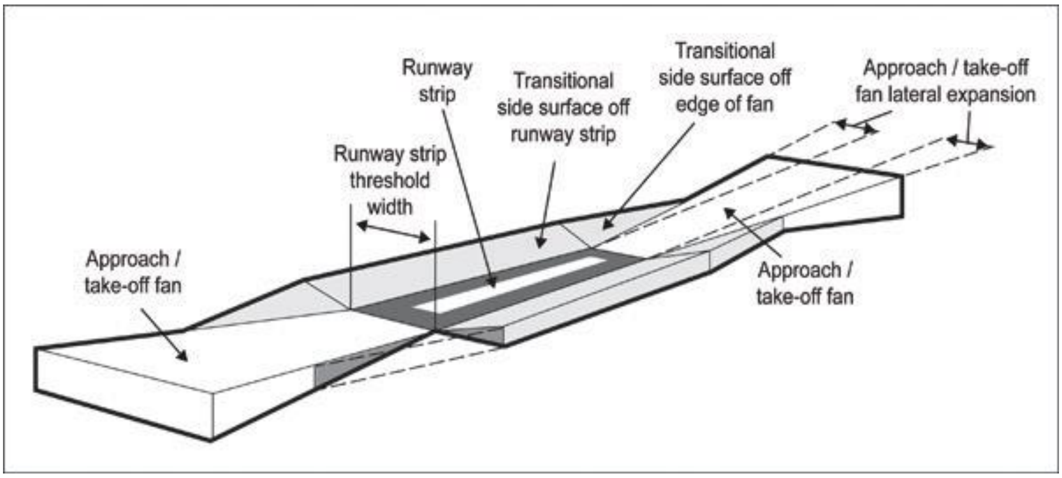
The term clear zone is used to indicate the innermost portion of the approach zone and it is to be provided at the ends of runways. The runway clear zones are the most critical portions from the view point of obstruction. It should be preferably a level area and except for fences, ditches and other minor obstructions, all the major obstructions should be removed from the clear zone.





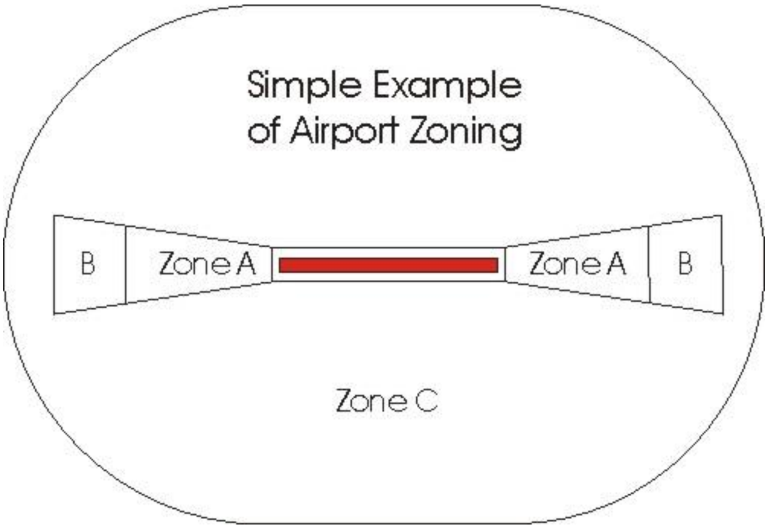
Approach zone

The approach zone is trapezoidal in shape. It is longitudinally centered on the extended center-line runway. It has upgrade from its beginning near that extremity of the runway which is on the landing side. Its sides diverge as they extend away from the extremity of the runway. It is applied to each end of a runway.



Buffer zone

The buffer zone is the area of airport other than the approach area and it is intended for turning operations of the aircraft in case of emergencies like failure of engine or trouble in smooth working of aircraft experienced at the start of the take off. In such case the pilot takes the turn and comes in line with the runway before landing.



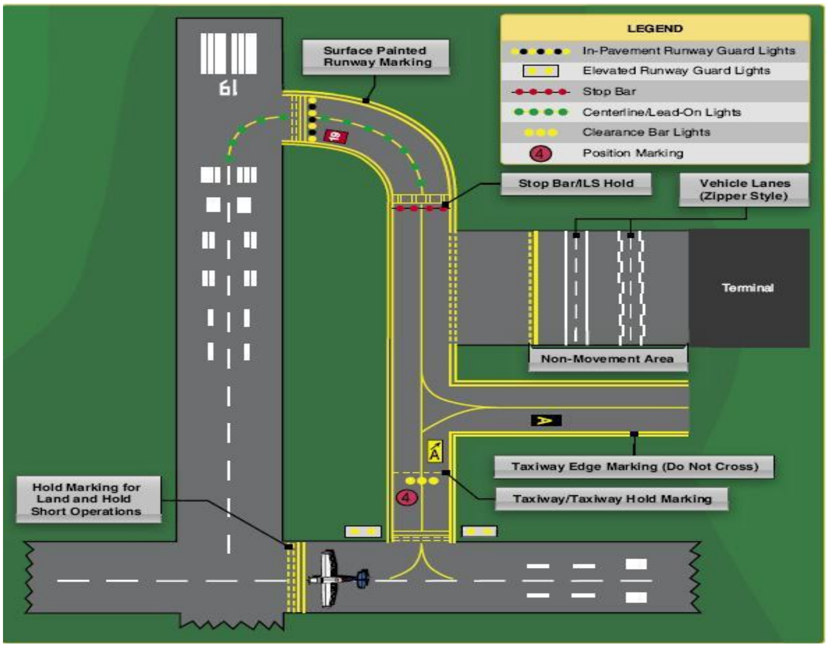
AIRPORT MARKINGS

- Land marks which are required so as to provide an aid to the pilots
    - ✓ Ensures the smooth operating of the air craft
- Required both in good weather and bad weather as well as during day and night
- The runways of the conventional aircraft appears as long and narrow strip with straight sides and free of obstacle
    - ✓ Marked in such a way they can be easily distinguishable from other areas

- The perspective view of the runways along with the landmarks like horizon, runway edges, runway threshold and centreline of the runway are the most important elements for pilot to see.
  - ✓ Centre line for aligning aircraft, horizon for flying, maintaining specific height from different elements like approach zone and similarly other things are needed to be identified
- Hence, to enhance visual information land marks are painted in standard formats using color or by using lights
- These are available in different forms of markings in the airport and airfield
  1. Airport markings
  2. Airport lighting
  3. Signage

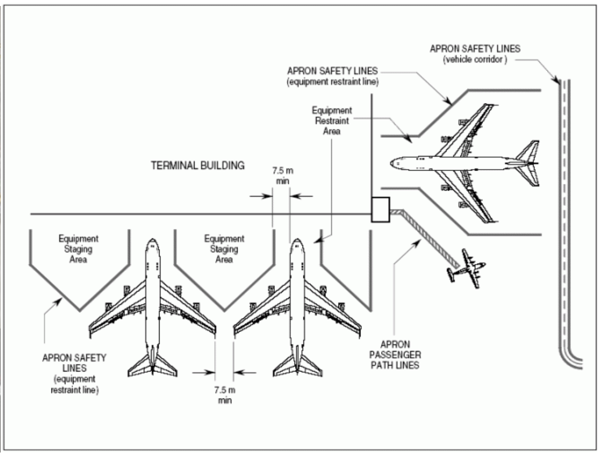
1. ***Airport makings***

- Markings are provided on any of the component of airport in different forms mentioned below
  a) Strips
  b) Patches
  c) Solid lines
  d) Hollow lines
  e) Cart lines
- Arrangement can be inclined, perpendicular to runway or a component or any other shape
- Airport markings can be divided into following groups
  a) Apron marking
  b) Landing direction indicator
  c) Runway marking
  d) Shoulder marking
  e) Taxiway marking
  f) Wind direction indicator



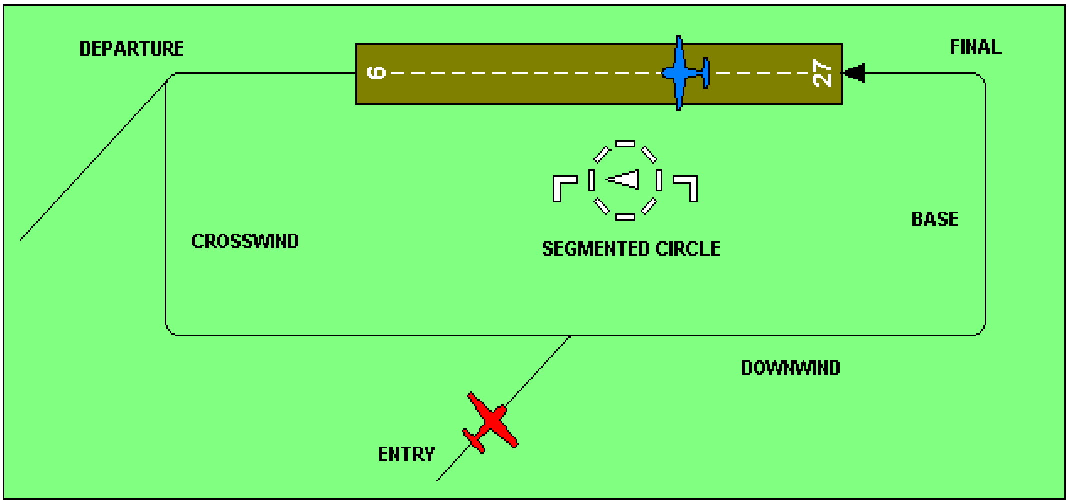
Apron marking

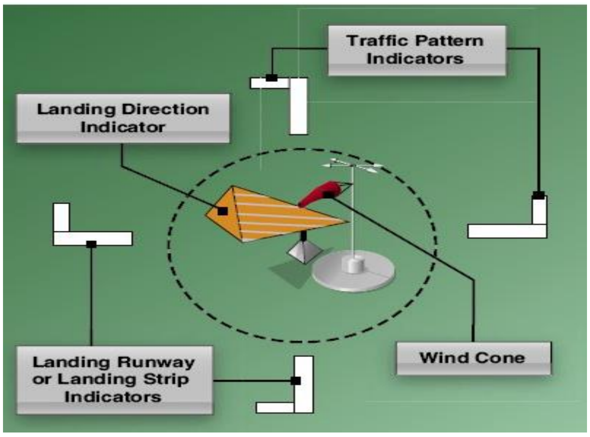
- How aircraft is going to take a turn?
- At what particular location it has to stop?
- Where there can be a loading and unloading, everything is defined by using apron markings?



Landing direction indicator

- To indicate the landing direction an arrow or a Tee is placed at the center of a segmented circle
  - ✓ Helps in identifying the runway strip and the direction from which they can land
  - ✓ Shape is arrow, or Tee or circle with cutoff lines
- It is painted in orange or white colour
- It is lighted for viewing during night time
- It is fixed at a distant place





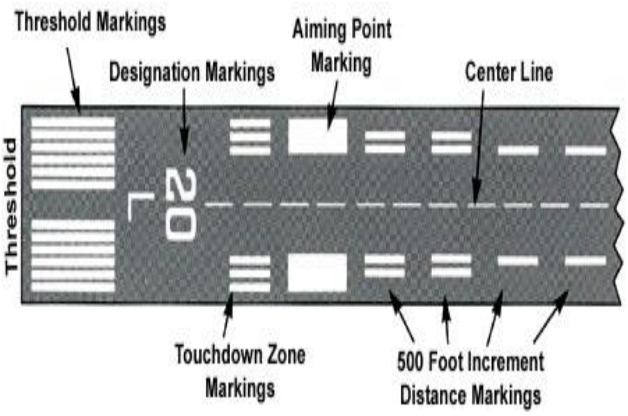
Segmented circle

RUNWAY MARKING

- These are provided with different purposes like
  - i. Runway center line marking
  - ii. Runway edge stripe
  - iii. Runway numbering
  - iv. Touch down or landing zone marking
  - v. Threshold marking
  - vi. Two or more parallel runways

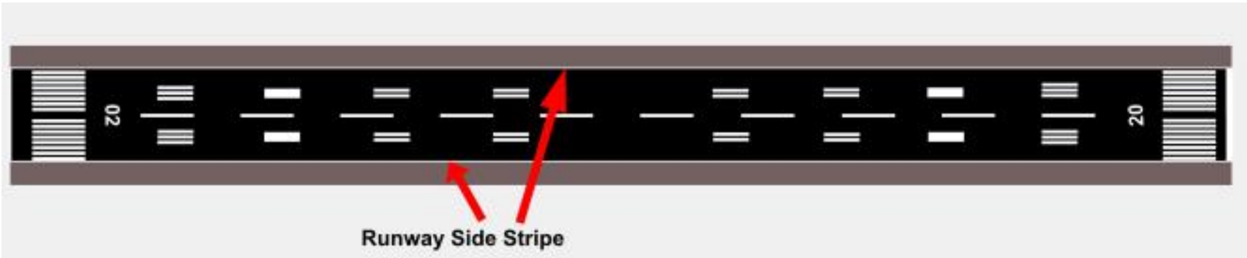
Runway Centerline marking

- It is represented by a broken strip running along the entire length of runway
- Length of strip should be equal to length of gap or 30m whichever is higher
- Length of strip plus gap shall not be less than 50m and more than 75m
- The width of strip shall not be less than 90cm on precision approach runway and 30cm to 45cm on non-precision approach runway



<u>Runway edge stripe</u>

- Runway edge strip consists of 2 stripes on along each edge of runway
- If width of runway is greater than 60m, the stripe should be located 30m away from the runway centerline
- The thickness of stripes is normally 90cm

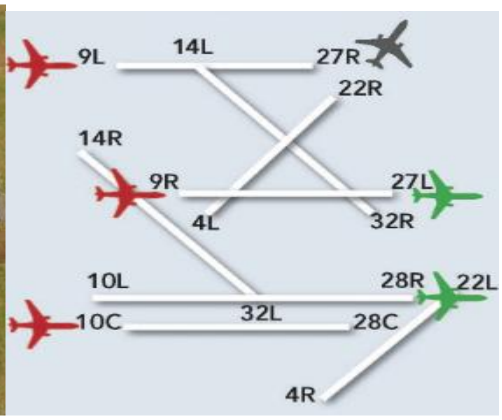


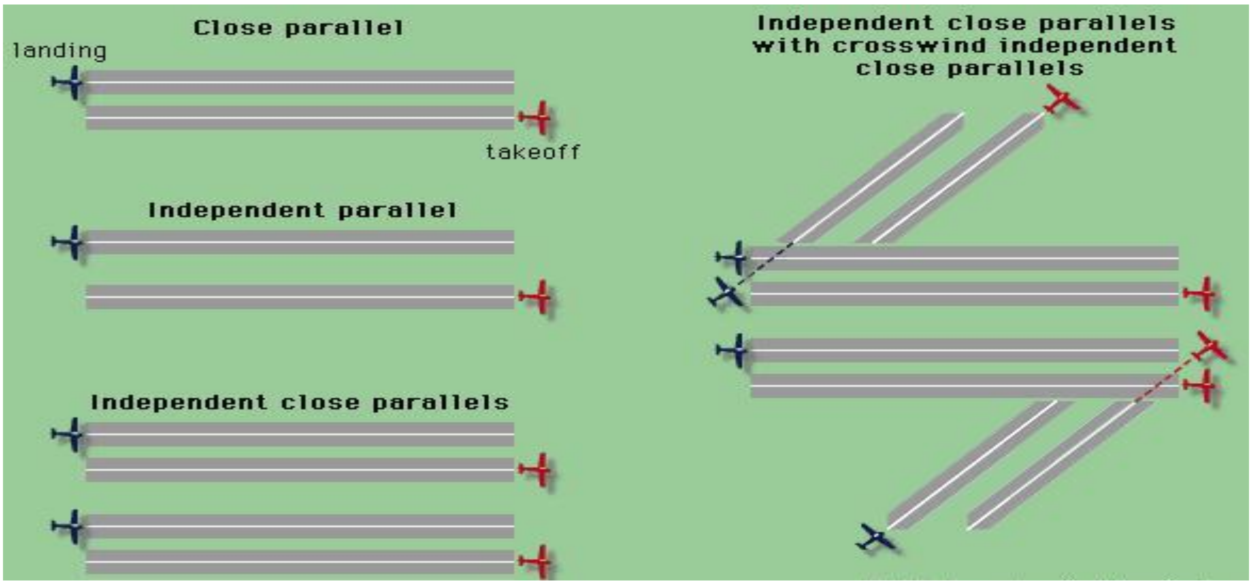
<u>Runway numbering</u>

- The end of runway is marked with a number that indicates magnetic azimuth
    - Angle measured in clockwise direction from north
- East end of East-West runway will be marked 27 (for 270 degree) and the west end is marked 9 for 90 degree
- Magnetic azimuth is marked to nearest 10 degree

Two or more parallel runways

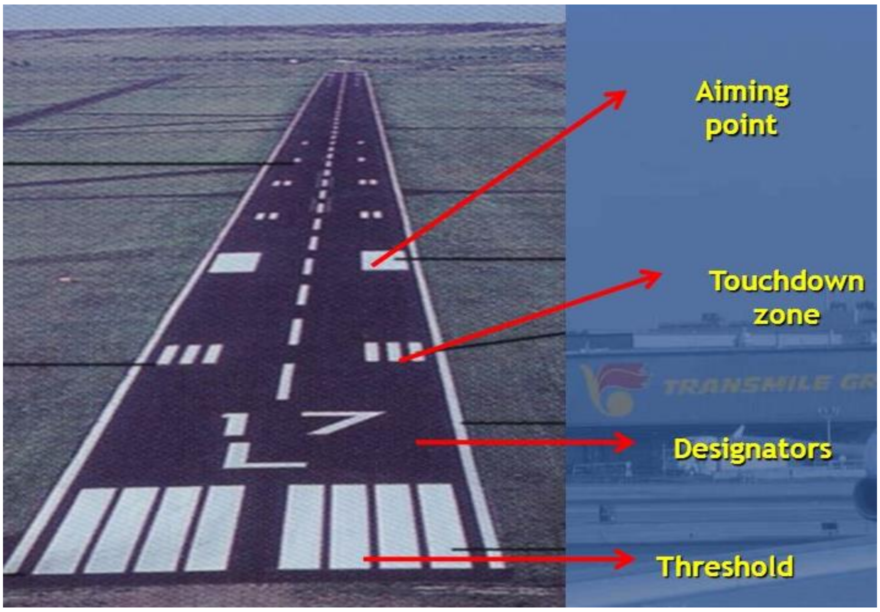
- If there are more than one runway in same direction following numbers are added to the azimuth numbers
  - a) 2 parallel runways – L, R
  - b) 3 parallel runways – L, C, R
  - c) 4 parallel runways – L, R, L, R
  - d) 5 parallel runways – L, C, R, L, R





Touch down or landing zone marking

- It is provided in the touch down zone and consists of pair of rectangular markings placed symmetrically about the runway center line
- These are 1.80m wide stripes spaced at 1.50m clear distance and are of 22.5m in length.

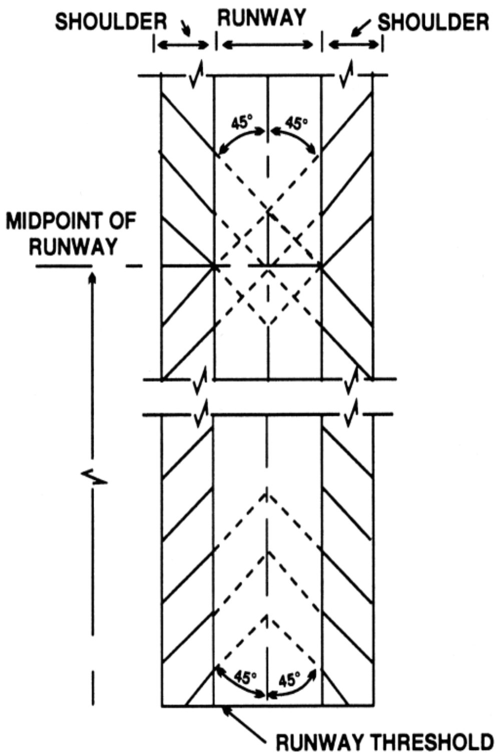


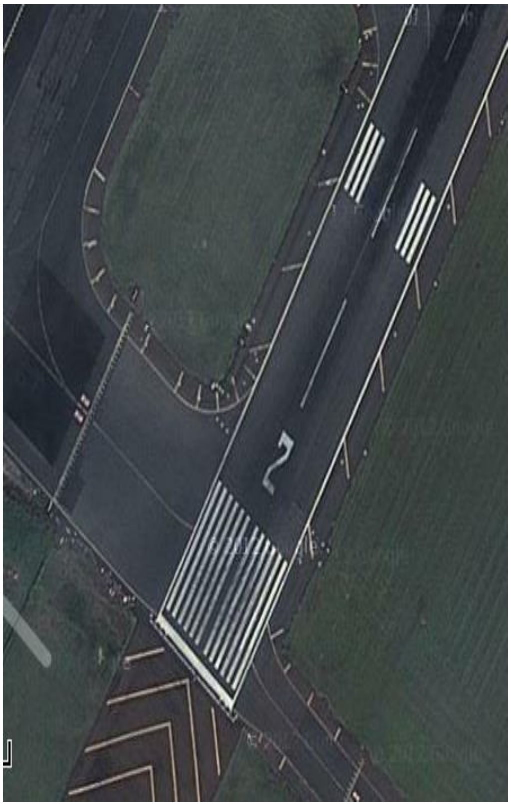
Runway Threshold Markings

- ➢ Runway threshold markings consists of a pattern of longitudinal stripes of uniform dimensions placed symmetrically about the centerline of a runway
- ➢ They extend laterally within 3m of the edge of the runway
- ➢ They are 1.80m/3.60m wide with a spacing of 1.80/0.90m between them and are 45m long.
- ➢ Usually provided to clear the obstructions in the flight path

Shoulder marking

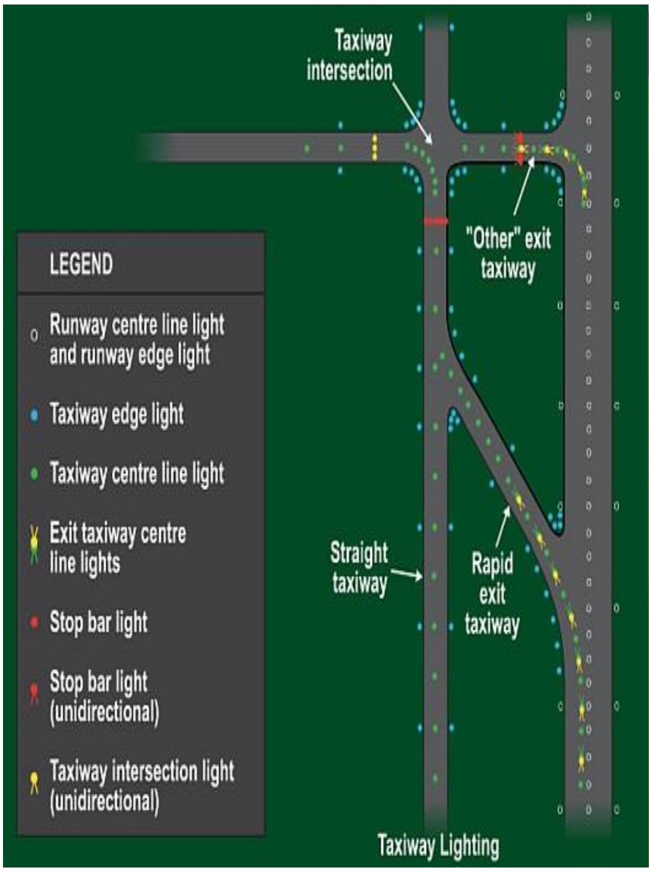
- ➢ Markings are in the form of yellow stripes , 90cm wide and 30m apart (15m at turnings)
- ➢ The markings extend up to a maximum 1.5m from the outer edge of shoulders
- ➢ Runway shoulders are marked with diagonal lines (45 degrees angle), whereas taxiways and holding apron shoulders are marked with stripes perpendicular to the direction of aircraft.
- ➢ Helps pilot in knowing whether they are moving towards runway or moving away from runway.
- ➢ Blast pad at the end of runway is marked with chevron or V shaped lines
    - ✓ This is the area or direction from which take off takes place.

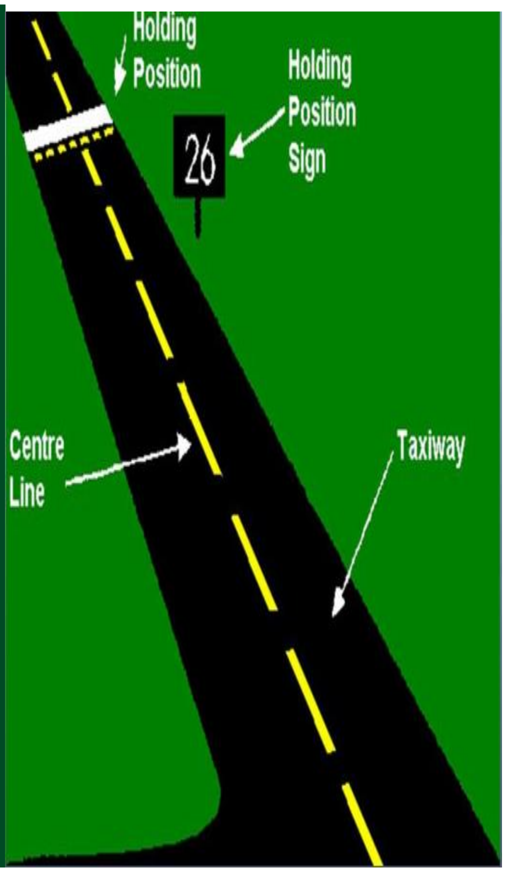




Taxiway marking

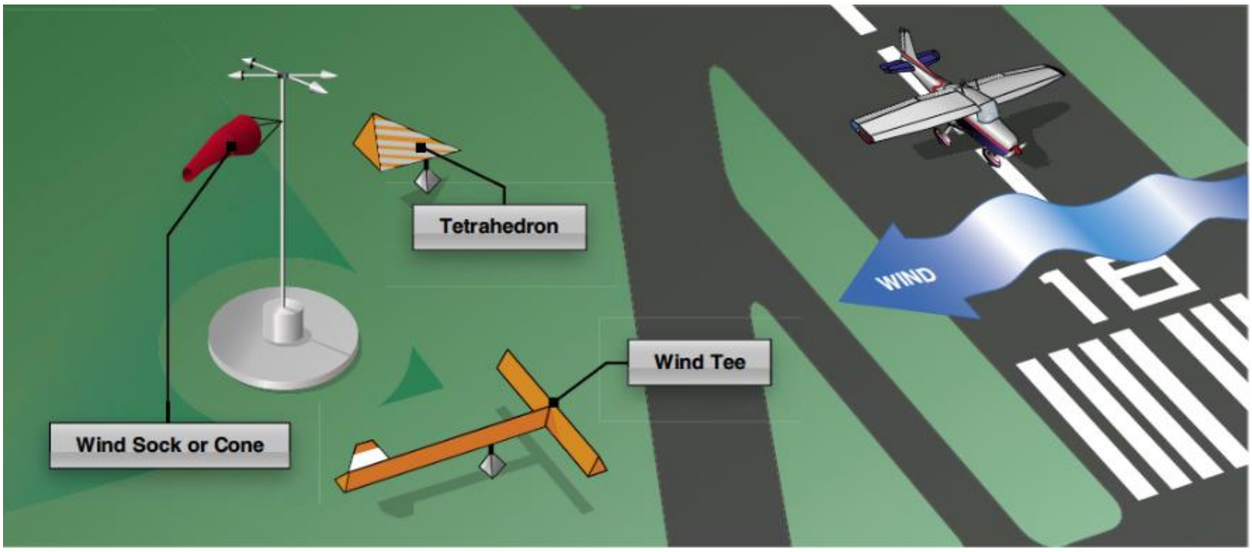
- Center line of taxiway consists of 15cm wide continuous stripe of yellow colour
- At intersection with runway end, the centerline of the taxiway is terminated at the edge of the runway
- At all other intersections with the runway, the centerline of the taxiway extends up to the centerline of runway
    - ✓ At other intersections with runway it will reach up to the centerline of runway and joins there.
- At the taxiway intersection, the centreline marking of the taxiway continue through the intersection area
- For taxiway intersection where there is a need to hold the aircraft, a dashed yellow holding line is placed perpendicular to and across the centreline of both taxiways
- at the intersection of runway with an exit taxiway, the taxiway markings are extended on to the runway parallel to the runway centreline, marking a distance of 60 meters beyond the point of tangency
- If a taxiway crosses a runway, the taxiway markings may continue across the runway, but with interruption for the runway markings.





Wind direction indicator

- The direction from which the wind blows is indicated by a wind cone
- It is placed in a segmented circle together with the landing direction indicator
- It should be placed away from buildings so that it is not effected by eddies
- Panels forming segmented circle are gable roof shaped with a pitch of atleast 1:1
- Panels are painted white
- Length of wind direction indicator should not be less than 3.6m and its diameter at the larger end should not be less than 90cm
- It should be visible from a height of 30m
- It is painted with bands of colors like white and black, red and white, orange and white etc.



Wind direction indicators.

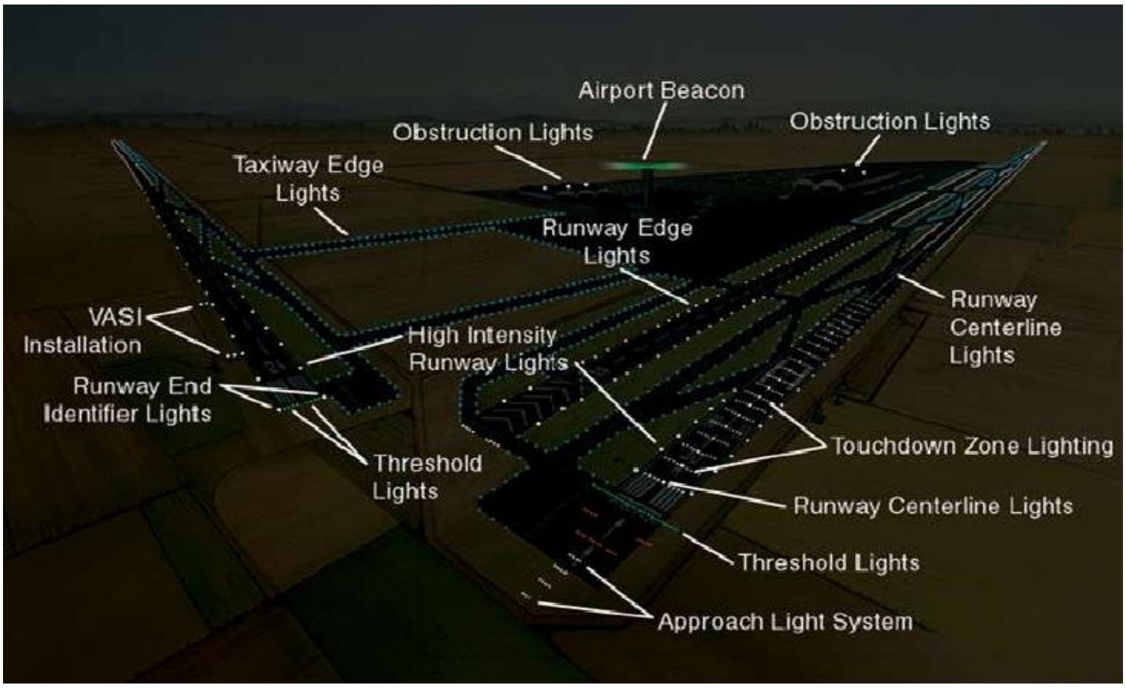
Closed runways or taxiways

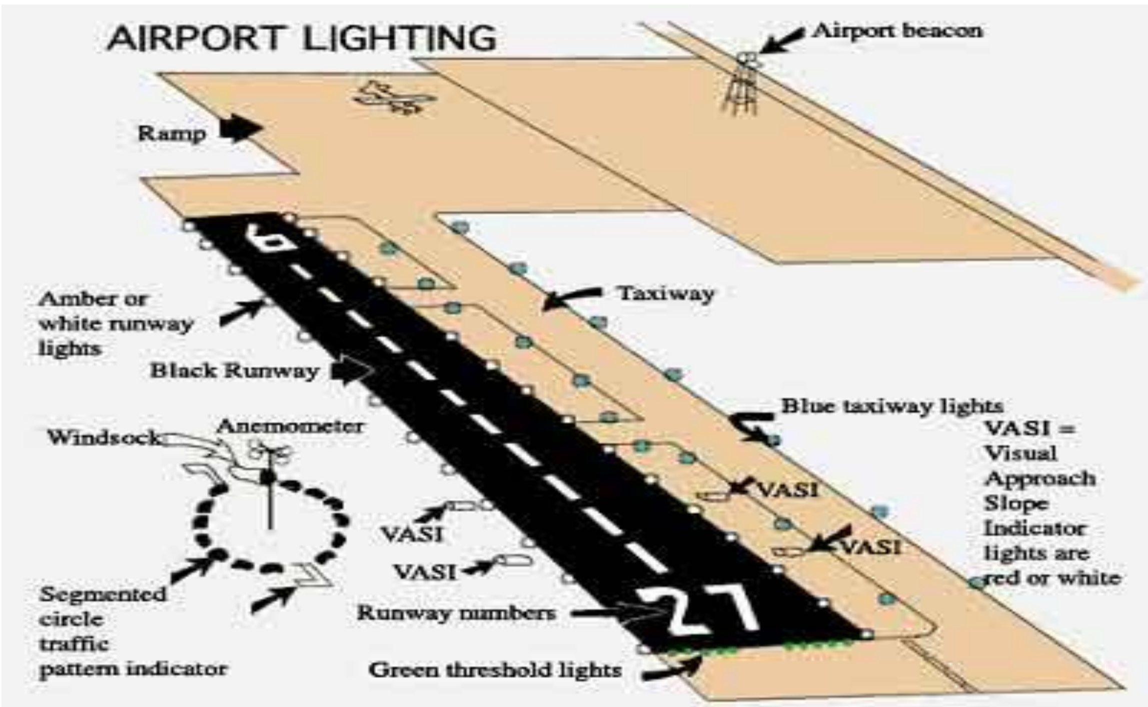
- ➢ For temporarily closed runways or taxiways, yellow crosses are placed at the two ends that defines it is temporarily closed.
- ➢ If the runway is closed permanently yellow crosses are placed at both ends and also at 300m intervals, then threshold markings provided are erased.

<u>AIRPORT LIGHTING</u>

- ➢ To achieve uniformity and to guide pilots for unfamiliar airports, colours and general arrangement of airport lights are standardized.
- ➢ Airport lights are kept clean, well-maintained, checked regularly for faulty bulbs and replacement.
- ➢ Tough and laborious job, major airport contains 30,000 lights

➢ Provision of emergency power supplies, which can take over in seconds in case of any power failure.





Factors affecting airport lighting

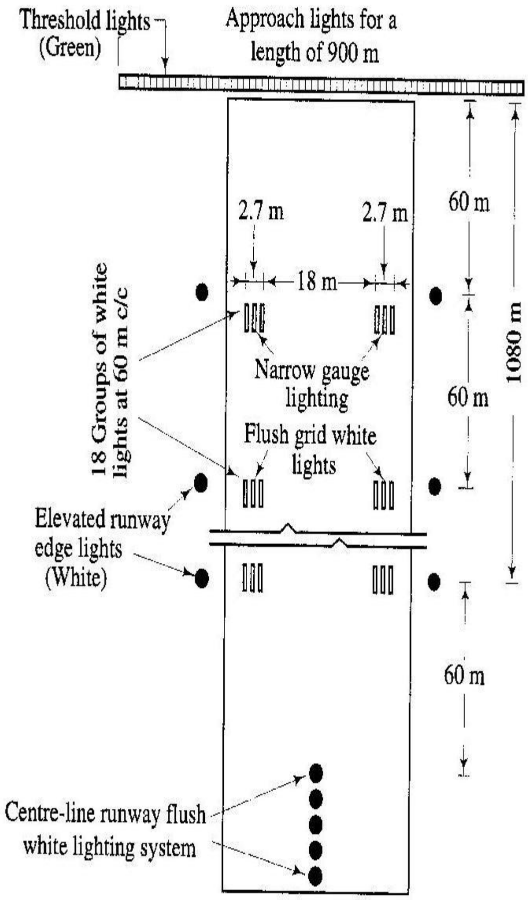
- ➢ Airport classification
- ➢ Amount of traffic
- ➢ Availability of power
- ➢ Nature of aircraft using the airport
- ➢ Type of night operation plans
- ➢ Type of landing surfaces provided
- ➢ Weather condition, etc.

Elements of airport lightening

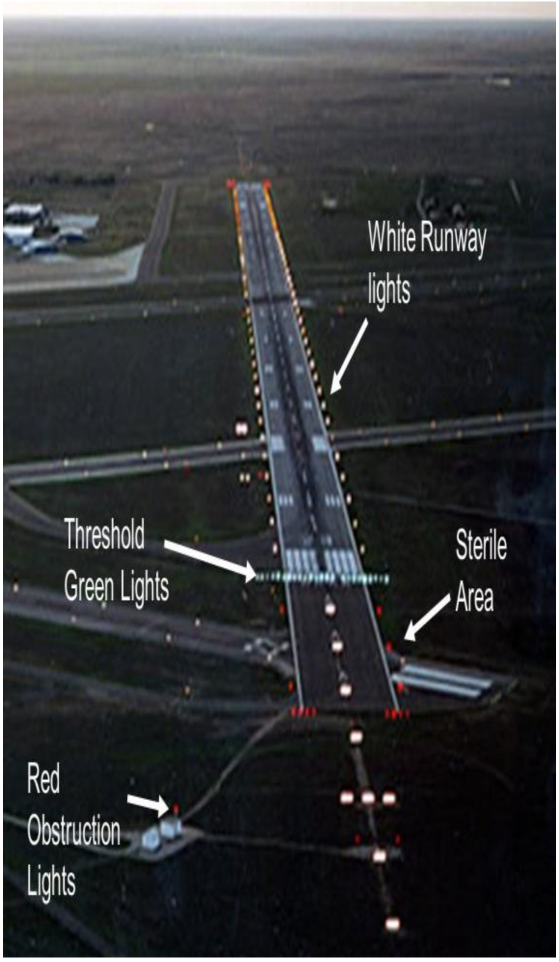
- Airport beacon
- Approach lighting
- Apron and hangar lighting
- Boundary lighting
- Lighting of landing direction indicator
- Lighting of wind direction indicator
- Runway lighting
- Taxiway lighting
- Threshold lighting

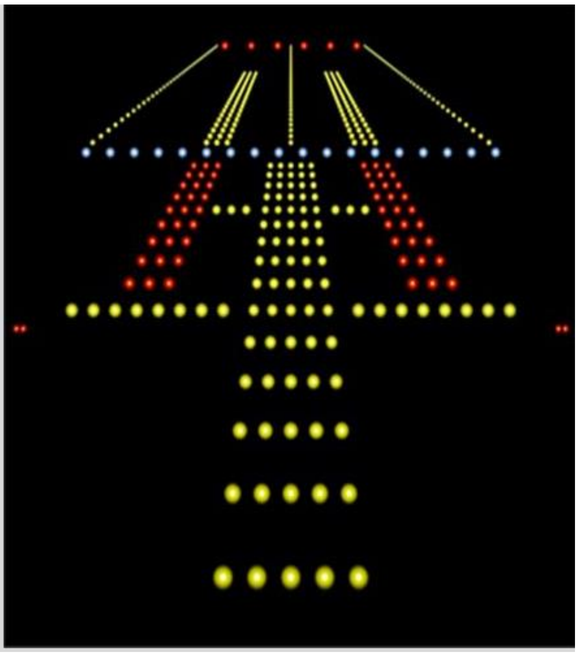
Runway lighting

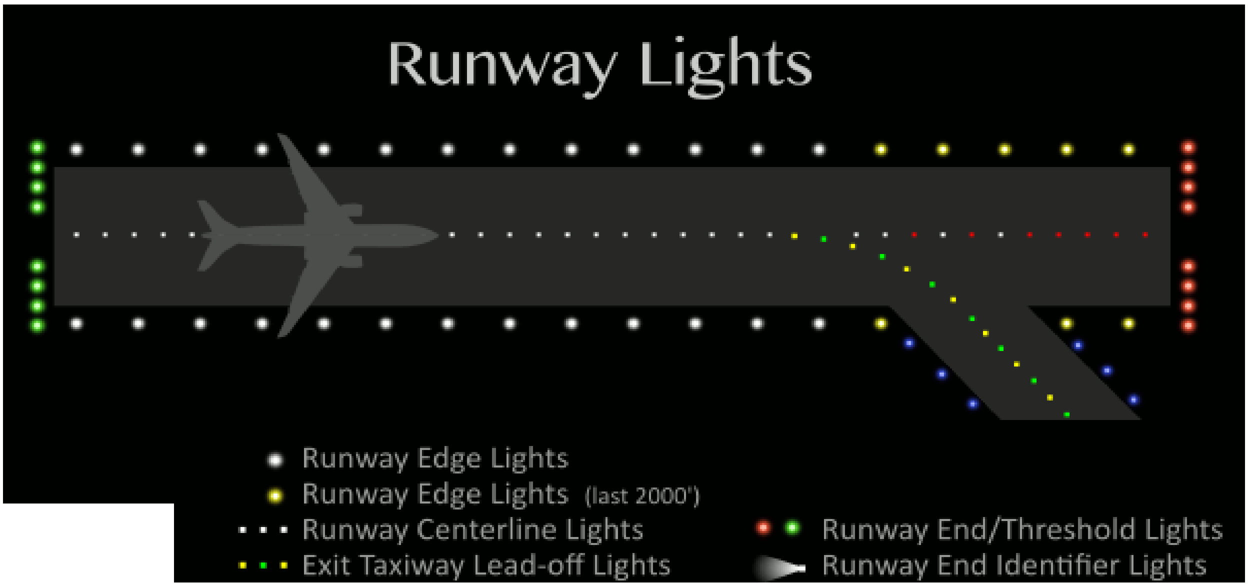
- After crossing the threshold, the pilot must complete a touchdown and roll out on the runway.
- The planning of runway lighting is carried out in such a way that the pilot gets enough information on alignment, lateral displacement, roll and distance.
- The lights are so arranged so that they form a visual pattern which the pilot can interpret easily.
- During night landings, flood lights were used in olden days. But now runway edge lights are adopted.
- Narrow gauge pattern- the most precise runway alignment which is widely used.
- It makes use of centre-line and touch down zone lights for operations in very poor visibility.
- Black hole effect: As the pilot crosses the threshold, and continues to look along the centre-line, the principal source of guidance, namely, the edge lights has moved far to each side in the peripheral vision. As a result, the central area appears black and the pilot is virtually flying blind for the peripheral reference information.
- This can be eliminated by adopting the narrow gauge pattern of the runway lighting, the central portion gets illuminated and the black hole effect is partly eliminated.
- The narrow gauge pattern forms a channel of light of 18m width up to 1140m from the threshold and beyond this distance; the closely spaced lights are placed along the centre-line of the runway extending up to the other end of the runway.
- All the lights provided on the runway are white in colour and of flush type, i.e. they do not protrude more than 1cm above the surface of pavement.
- The runway edge lights are of elevated type and they are white colour except for the last 400m if an instrument runway facing the pilot which are of yellow colour to indicte a caution zone.



Narrow gauge pattern for runway lighting

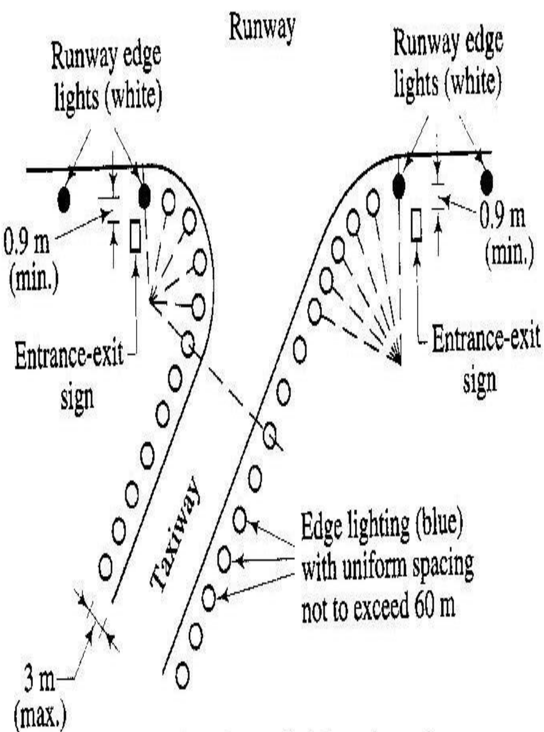




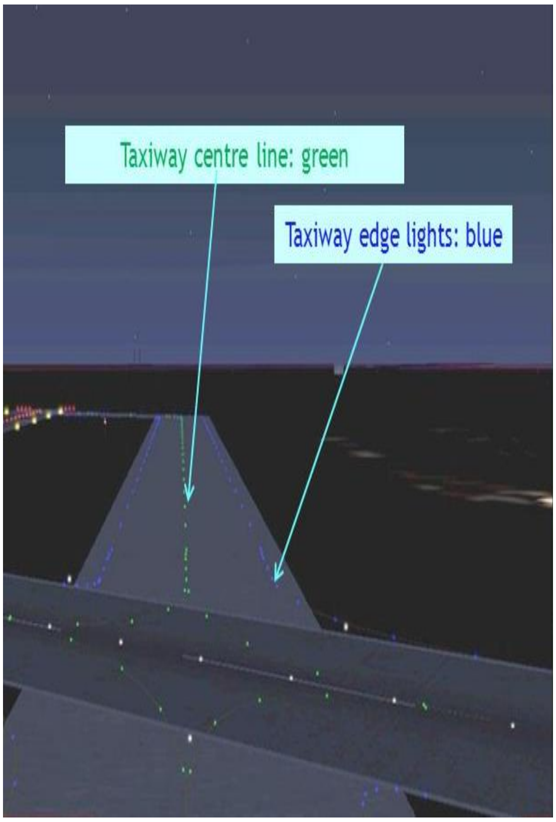


Taxiway lighting

- The pilots have to manoeuvre the aircrafts on a system of taxiways to and from the terminal and hangar areas either after landing or on the way to take off
- The taxiway system is much complicated on large airports and therefore it is necessary to provide adequate lighting at night and at daytime when the visibility is very poor
- For normal exits- centreline terminated at the edge of the runway.
- At taxiway intersections, the lights continue across the intersection. They are placed at a distance of 6m to 7.5m along the straight length and 3m to 3.6m along the curves.
- The complete route from the runway to the apron should be easily identified.
- The edge lights should not extend more than 75cm above the pavement surface.
- The exits from the runways should be so lighted that the pilots are able to locate the exits 360m to 400m ahead of the point of turn.
- The intersection of taxiways and runways-taxiway crossings should be clearly marked.
- The lights on the tangent portion are placed not more than 60m apart and the distance from the edge along the curves and the intersections to facilitate easy identification. The spacing varies from 6m for curve of radius 4.5m to 60m for a curve of 300m.
- There should be adequate guidance along the taxiway.
- The taxiway edge lights are blue and the taxiway centre lights are green.
- The taxiway should be clearly identified so that they are not confused with the runways.



Typical taxiway lighting layout



DESIGN STANDARDS AND PLANNING OF AIRPORT AS PER INDIAN CONDITION.

The ICAO uses a two-element code, the aerodrome reference code, to classify the geometric design standards at an airport. The code elements consist of a numeric and alphabetic designator. The aerodrome code numbers 1 through 4 classify the length of the runway available, the reference field length, which includes the runway length and, if present, the stop way and clearway. The reference field length is the approximate required runway takeoff length converted to an equivalent length at mean sea level, 15°C, and zero percent gradient.

Airports are divided into landside and airside areas. Landside areas include parking lots, public transportation train stations and access roads. Airside areas include all areas accessible to aircraft, including runways, taxiways and aprons.

Access from landside areas to airside areas is tightly controlled at most airports. Passengers on commercial flights access airside areas through terminals, where they can purchase tickets, clear security check, or claim luggage and board aircraft through gates. The waiting areas which provide passenger access to aircraft are typically called concourses, although this term is often used interchangeably with terminal.

The designer of an airport has to consider that airport designed to cope up with the current traffic, but also to manage with traffic likely to occur in future period.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – V – Railways, Airport and Harbour Engineering – SCIA1701

V. Waterways

Introduction - General terminologies - Ports: Classification, Requirements - Docks: Classification - HARBOUR: Classification, Requirements -- HARBOUR Layout and Terminal Facilities - Coastal Protection Structures - Breakwaters: Classification - Signals: floating and fixed - light house and beacon-Inland Water Transport- Container transportation.

INTRODUCTION

Movement on land is easy through roadways and railways but area available is nearly one-third of entire earth surface. On the contrary two third of entire earth surface is covered by water which proves importance of waterways or water transportation. A waterway is any navigable body of water. A shipping route consists of one or several waterways. Waterways can include rivers, lakes, seas, oceans, and canals.

Advantages of water transportation

- ❖ It assists and provides a powerful means of defence in the emergency of national security.
- ❖ It is the cheapest mode of communication because rail and road transport require a special tracks.
- ❖ It leads the overall development of commerce, industries and international trade.
- ❖ It possesses high load carrying capacity.
- ❖ It encourages consumption of foreign goods.
- ❖ It require cheap motive power for its working.

Disadvantages of water transportation

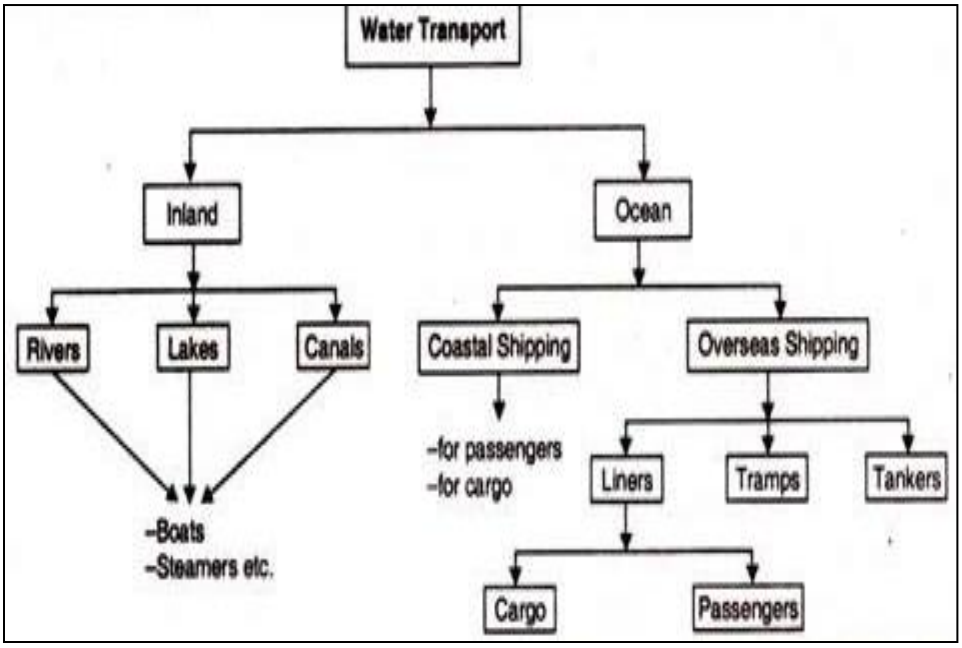
- ❖ It is slow and consumes more time due to slow speed and circuitous routes.
- ❖ It is use when water is available as the mode of transport and that too, along particular routes only
- ❖ It may lead to accidents in case of frequent ocean storms and hurricanes causing great loss of cargos.
- ❖ There are more chances of attack by other countries
- ❖ The fluctuation of water level will cause the rubbing of sides of ship against the berth.
- ❖ The fleets of water ships are used exhibition of power and political domination.

Classification of waterways

Kinds of Water Transport

Water transport consists of

A. Inland water transport
B. Ocean-transport



Inland Water Transport

As shown in the chart, inland water transport consists of transport by rivers, canals and lakes.

Rivers - Rivers are a natural waterway which can be used as a means of transport. They are suitable for small boats as well as big barrages. River transport played a very important role prior to the development of modern means of land transport. Their importance has gradually declined on account of more reliable and cheaper transport services offered by the railways.

Canals - They are artificial waterways made for the purpose of irrigation or navigation or both. Canal transport requires a huge amount of capital investment in construction and maintenance of its track i.e., the artificial waterways. The cost of the canal transport is, therefore, higher than that of river transport. To add to it, the cost of providing water for the canals is also a very big problem of canal transport.

Lakes - Lakes can be either natural like rivers or artificial like canals.

Advantages

Low Cost - Rivers are a natural highway which does not require any cost of construction and maintenance. Even the cost of construction and maintenance of canals is much less or they are used, not only for transport purposes but also for irrigation, etc. Moreover, the cost of operation of the inland water transport is very low. Thus, it is the cheapest mode of transport for carrying goods from one place to another.

Larger Capacity - It can carry much larger quantities of heavy and bulky goods such as coal, and, timber etc.

Flexible Service - It provides much more flexible service than railways and can be adjusted to individual requirements.

Safety - The risks of accidents and breakdowns, in this form of transport, are minimum as compared to any other form of transport.

Disadvantages

Slow - Speed of Inland water transport is very slow and therefore this mode of transport is unsuitable where time is an important factor.

Limited Area of Operation - It can be used only in a limited area which is served by deep canals and rivers.

Seasonal Character - Rivers and canals cannot be operated for transportation throughout the year as water may freeze during winter or water level may go very much down during summer.

Unreliable - The inland water transport by rivers is unreliable. Sometimes the river changes its course which causes dislocation in the normal route of the trade.

Unsuitable for Small Business - Inland water transport by rivers and canals is not suitable for small traders, as it takes normally a longer time to carry goods from one place to another through this form of transport.

<u>Ocean transport</u>

Ocean transport is indispensable for foreign trade. It has brought the different parts of the world closer and has knitted together all the nations of the world into one big world market. It operates on a natural track, i.e., the sea and does not require any investment in the construction and maintenance of its track. It is, obviously, the cheapest mode of transport.

Ocean transport includes

1. Coastal Shipping
2. Overseas Shipping

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

Overseas Shipping - There are three types of vessels employed in the overseas shipping:

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

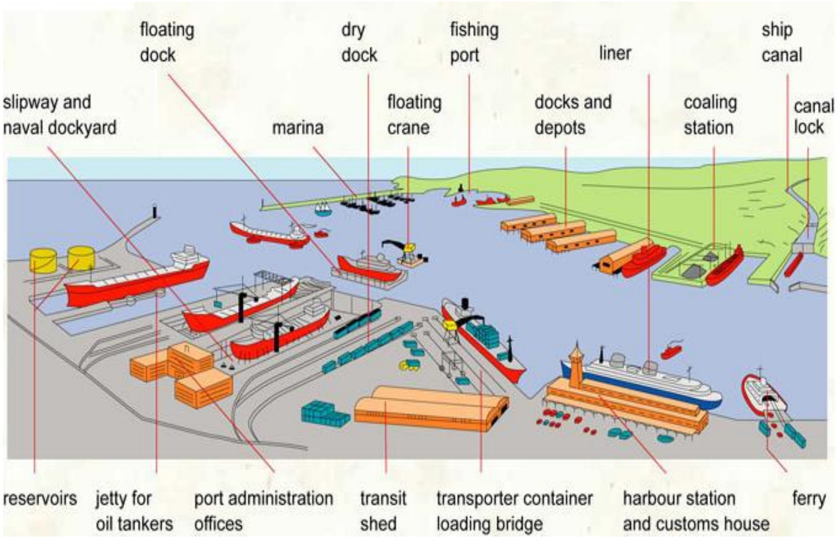
Tramps - Tramps are ships which have no fixed routes. They have no set rules or rate schedule. Usually, they do not sail till they have full cargo. They can be chartered by exporters and are ready to sail anywhere and at any time. They are not as fast in speed as liners. Tramps are more suitable to carry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

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

Advantages

- It operates on a natural track as sea provides a readymade 'road bed' for the ships to sail. Hence, it does not require huge amount of capital investment in the construction and maintenance of its track.
- Due to the smooth surface of sea, comparatively less tractive power is required for its operation which results in a lesser cost of operation. Thus, it is the cheapest mode of transport.
- It has the largest carrying capacity as compared to any other transport. But the goods are exposed to the 'perils of sea'.
- It is the only suitable mode of transport for carrying heavy and bulky goods to distant places.
- It is indispensable to foreign trade.

GENERAL TERMINOLOGIES



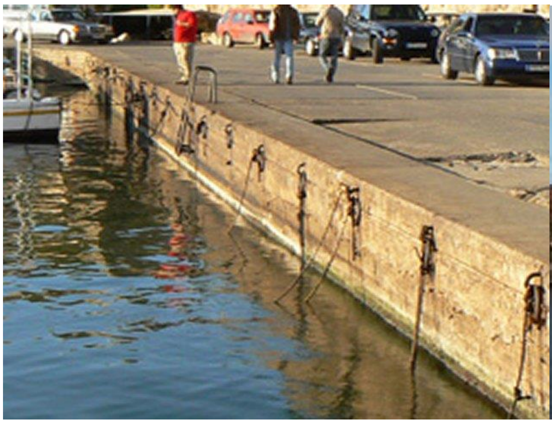
WHARF

A wharf is a ***structure extending parallel with the shoreline, connecting to the shore at more than one point*** (usually with a continuous connection), and providing, in most cases, berthing at the out shore face of the structure only. It is a landing place or platform built into the water or along the shore for the berthing of vessels.

It is probably the oldest of these terms, and it applies to any structure projecting from the shore that permits boats or ships to lie alongside for loading or unloading. It is typically a structure of ***timber, masonry, concrete, earth, or other material*** built along or at an angle from the shore of navigable waters (as a HARBOUR or river).

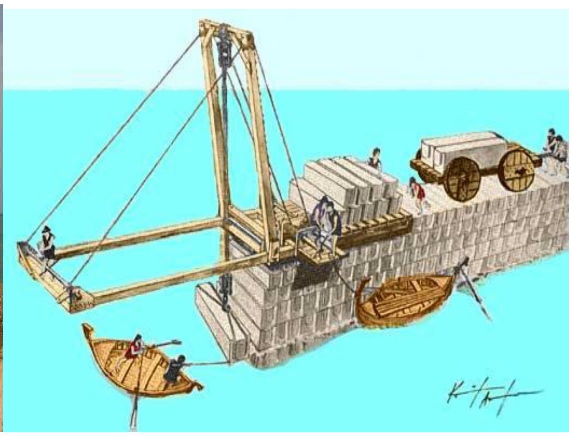

QUAYS

A quay is an artificial wall or bank, usually of stone, made toward the sea or at the side of a HARBOUR or river for convenience in loading and unloading vessels. It is a structure of ***solid construction along a shore or bank that provides berthing*** and generally provides cargo-handling facilities. A quay usually refers to an artificial embankment lying along or projecting from a shore and mainly used for loading and unloading. A similar facility of open construction is called a wharf.




MOLES

A mole is ***a massive structure, usually of stone, used as a pier, breakwater, or a causeway between places separated by water***. A mole may have a wooden structure built on top of it that rather resembles a wooden pier. The defining feature of a mole, however, is that water cannot freely flow underneath it, unlike a veritable pier

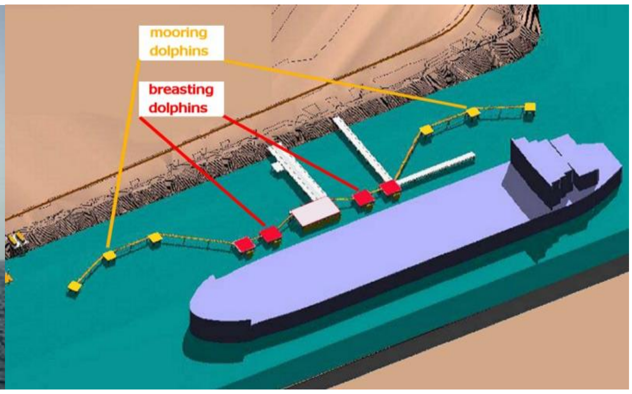
<u>JETTIES</u>

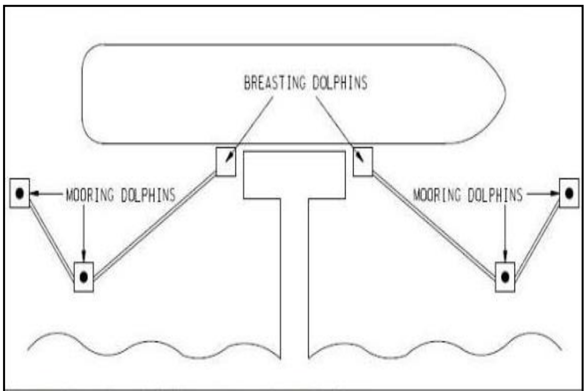
A jetty is any of a variety of structures used in river, dock, and maritime works that are generally carried out in pairs from river banks, or in continuation of river channels at their outlets into deep water; or out into docks, and outside their entrances; or for forming basins along the coast for ports in tide less sea. The forms and construction of these jetties are as varied as their uses (directing currents or accommodating vessels), for they are formed sometimes of high open timber-work, sometimes of low solid projections, and occasionally only differ from breakwaters in their object. A jetty is ***a structure that projects from the land out into water***. It refers to ***a walkway accessing the centre of an enclosed water body***.

DOLPHINS

A dolphin is ***a structure consisting of a number of piles driven into the seabed or river bed in a circular pattern and drawn together with wire rope***. It may be used as part of a dock structure or a minor aid to navigation. A ***dolphin is commonly used when a single pile would not provide the desired strength***. These may be either breasting dolphins or mooring dolphins. The breasting dolphins are used to carry the lateral load during vessel impact, transferred through an energy-absorbing fendering system. A breast line is a mooring or dock line extended laterally from a vessel to a pier or float, as distinguished from a spring line.





Breasting dolphin and mooring dolphin

FENDERS

In boating, a fender is a bumper used to absorb the kinetic energy of a boat or vessel berthing against a jetty, quay wall or other vessel. Fenders are used to prevent damage to boats, vessels and berthing structures. Fenders are typically manufactured out of rubber, foam elastomer or plastic. Rubber fenders are either extruded or made in a mould. The type of fender that is most suitable for an application depends on many variables, including dimensions and displacement of the vessel, maximum allowable stand-off, berthing structure, tidal variations and other berth-specific conditions. The size of the fender unit is based on the berthing energy of the vessel which is related to the square of the berthing velocity.




TYPES OF FENDERS

1. SHIP TO QUAY (STQ)

Marine fenders are used at ports and docks on quay walls and other berthing structures. They absorb the kinetic energy of a berthing vessel and thus prevent damage to the vessel or the berthing structure. The many types of marine fenders include:

1. Cylindrical fenders
2. Arch fenders
3. Cell fenders
4. Cone fenders
5. Pneumatic fenders
6. Foam elastomer fenders

2. SHIP-TO-SHIP (STS)

For bunkering operations between two vessels, floating fenders such as pneumatic or foam elastomer fenders are typically used.

3. BOAT

Boat fenders are used on recreational boats, tugboats, ferries, naval vessels, passenger vessels, luxury yachts etc. Boat fenders are also available in different types, such as:

1. D fenders
2. Square fenders
3. Wing fenders
4. Keyhole fenders
5. Tug boat fenders
6. Lightweight foam elastomer fenders

Cylindrical fenders

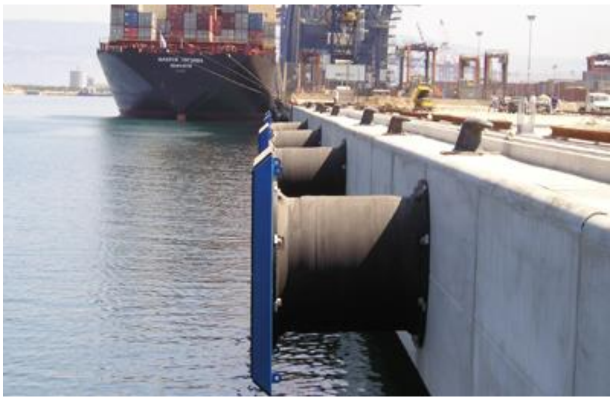
Cylindrical fenders are commonly used fenders which ensure a safe and linear berthing for different kinds of vessels. Cylindrical (extruded) fenders are an economical solution to protect most berthing structures, and offer ease of installation.


Arch fenders

Arch fenders were introduced to improve upon the performance of cylindrical fenders. Arch fenders have a better Energy / Reaction force ratio and recommended for all types of applications. The shape of these fenders helps to dissipate the stresses evenly. These extruded fenders are very easy to install and are maintenance free. This is generally preferred for small to medium range vessels.

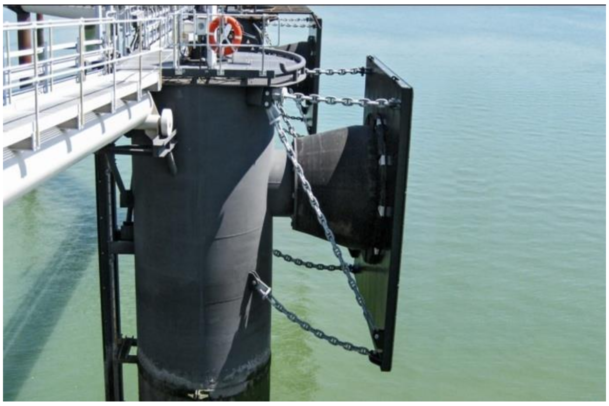

Cell fenders

Cell fenders are best employed for small or large vessels where Reaction Force is an important criterion. Among all types of fenders, Cell fenders offer minimum reaction per ton-meter energy absorbed. The very geometric shape gives it sturdiness, shear resistance, compact structure and the capacity to absorb energy equally from all directions. The Cylindrical buckling column absorbs axial loads effectively and buckles radially. This results in multi-directional dispersion of energy. Cell fenders are the most durable rubber fenders available and are currently the largest molded fenders made. 2000–2500 mm high cell fenders are typically used for LNG berths. In order to distribute the reaction force, cell fenders are typically supplied with large fender panels, which keep the hull pressure low.



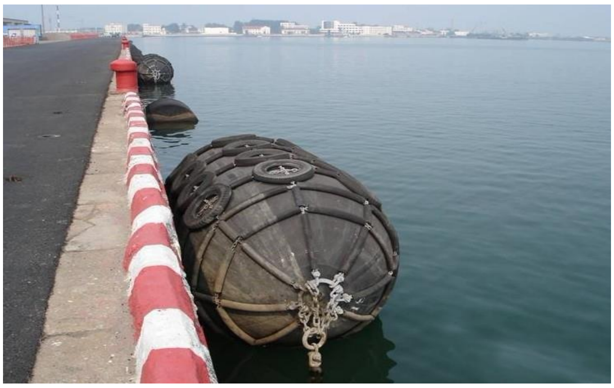

Cone fenders

Cone fenders are an improved version of Cell type Fender recently introduced and recommended for all types of applications including high tidal variation sites. This advanced feature of lesser height of fenders improves material handling capabilities of Deck / Vessel Cranes which reduces overall cost of the project. Due to the geometrical shape of the fenders it can deflect more and it can absorb more energy from any direction. Maintaining reaction force, but doubling energy absorption, can be achieved by using two identical cone fenders in a back-to-back arrangement. In order to distribute the reaction force, cone fenders are typically supplied with large fender panels, which keep the hull pressure low.

Pneumatic fenders

These fenders are extensively used for ship to ship transfers at mid seas, double banking operation as well as vessel to berth at dock/jetties. The special property of a Pneumatic fender is its low reaction force at low Deflection. This very property of pneumatic fenders makes them most suitable fender for liquid cargo vessels and defense vessels with very sensitive equipments. These fenders have excellent energy absorption characteristics and linear Load Deflection characteristics.

Foam elastomer fenders

These fenders are typically made of a closed-cell Polyethylene foam core, which is encapsulated in nylon or Kevlar reinforced Polyurethane skin. The performance of foam elastomer fenders is comparable to that of a pneumatic fender, but the fenders will not lose their function in case the skin gets punctured. Foam elastomer fenders cannot collapse.


D fenders

D type fenders are commonly used on vessels as well as small jetties. They are compression molded with steel inserts if required.


Square fenders

Square fenders are commonly used on vessels as well as small jetties. They are compression molded fenders generally used on tugs, boats and ships.

Wing fenders

Wing fenders are compression molded fenders and are generally used on tugs, boats and ships. Easy to install and replace. Do have excellent sea water resistance and resistance to ozone ageing and ultra violet rays.

Keyhole fenders

Keyhole fenders are the most versatile bow, stem fenders used on Tug Boats and small Port Craft/Ferries. They offer maximum protection to Tugs/Ferries with their typical profile and load absorbing capabilities.

Tug boat fenders

These fenders are made of high abrasion resistance rubber with good resilience properties. They are very popular with small port craft owners and tug owners. These fenders are compression molded in high pressure thermal fluid heated moulds and have excellent sea water resistance.


TRESTLES

A trestle (sometimes trestle) is a rigid frame used as a support, especially referring to a bridge composed of a number of short spans supported by such frames. In the context of trestle bridges, each supporting frame is generally referred to as a bent. Timber and iron trestles were extensively used in the 19th century, the former making up from 1 to 3% of the total length of the average railroad. In the 21st century, steel and sometimes concrete trestles are commonly used to bridge particularly deep valleys while timber trestles remain common in certain areas.

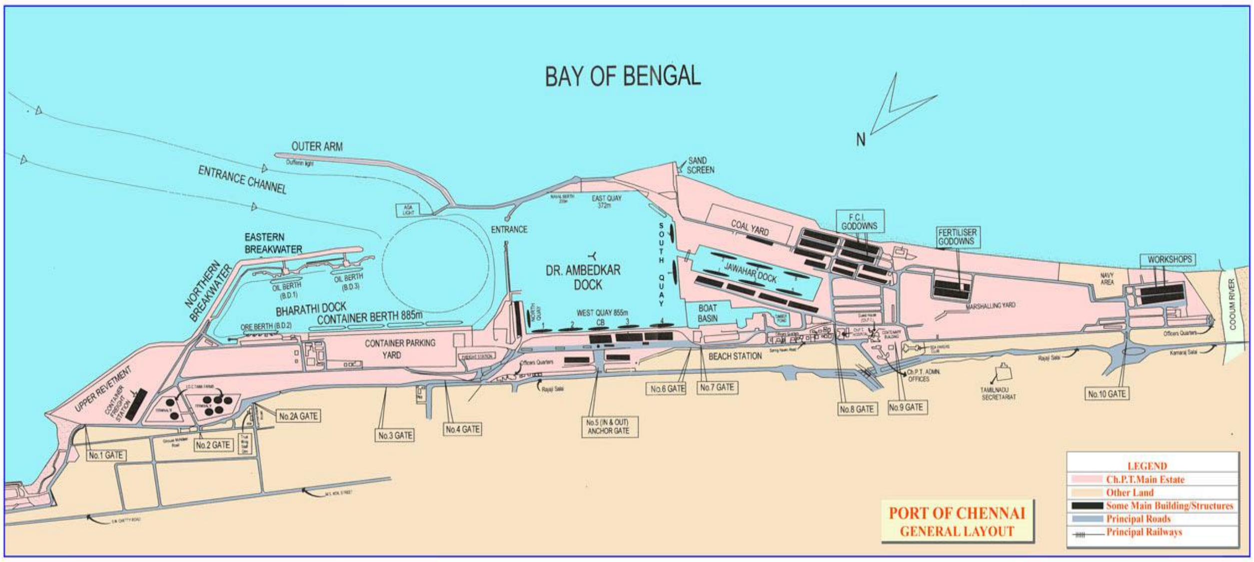

PORTS

A port is a harbour where marine terminal facilities are provided. A port is a place which regularly provides accommodation for the transfer of cargo and passengers to and from the ships.

Port = Harbour + Storage Facility + Communication Facility + Other Terminal Facility

From above,

It can be stated that ***a port includes a harbour i.e. every port is a harbour***.

The constituents of a port can be enlisted as follows,

- Entrance channel
- Approach channel
- Turning basin to allow gradual turning of the ship
- Berthing basin
- Breakwaters
- Quays and wharves
- Jetties and piers
- Docks
- Slipways and
- Other ancillaries such sheds, buoys, lights, fire protection towers, etc

Requirements of good port

- It should be centrally situated for the hinterland. Foe a port, the hinterland is that part of the country behind which it can served with economy and efficiency by the port
- It should get good tonnage
- It should have good communication with the rest of the country through rail and highways so that the commodities can be transported to and from the port easily and quickly
- The hinterland should be fertile with a good density of population
- It should be advanced in culture, trade and industry
- It should be place of defense and for resisting the sea-borne invasion
- It should be capable of easy, smooth and economical development
- It should afford shelter to all ships and at all seasons of the year
- It should provide the maximum facilities to all the visiting ships including the servicing of ships

Facilities at major port

- Protection facilities
- Dredging facilities

- Entrance facilities
- Guiding facilities
- Locking facilities
- Turning facilities
- Docking facilities
- Loading and unloading facilities
- Storage facilities
- Repairing facilities
- Administrative facilities
- Offshore terminal facilities
- Quarantine inspection facilities

CLASSIFICATION OF PORTS

Ocean Port - This is a port intended for large ocean going ships.
River Port - River port is located on the banks of the river inside the land.
Entry Port - This is location where foreign citizens and goods are cleared through custom house.
Free Port - This is an isolated and enclosed area within which goods may be landed, stored, mixed, repacked, manufactured and reshipped without payment of duties.

DOCKS

Docks are enclosed areas for berthing the ships to keep them afloat at a uniform level to facilitate loading and unloading cargo. A dock is ***a marine structure for berthing of vessels for loading and unloading cargo and passengers***.

Docks are necessary for discharging of the cargo as ships require a number of days for discharging cargo, during which period they need a uniform water level. If ship is subjected to a vertical movement by the tides, great inconvenience will be felt in lifting the cargo from the ship and special arrangement will be needed for lifting the cargo.

Classification of docks

Docks can be classified into following two categories:

- Wet docks.
- Dry docks.

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

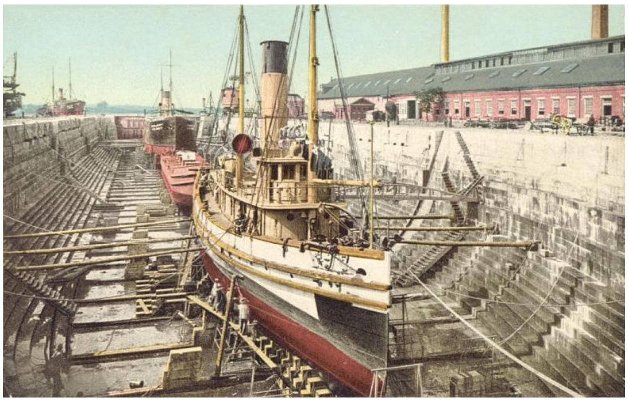
DRY DOCKS - The docks used for repairs of ships are known as dry docks.

<u>Classification of Dry docks</u>

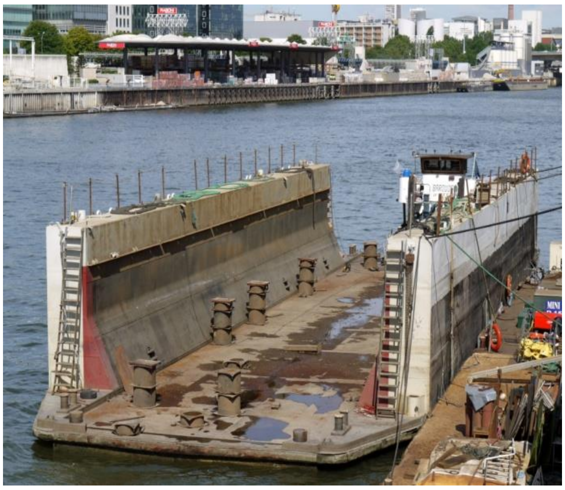
Dry docks are classified in the following five categories:

- Graving or dry docks.
- Floating dry dock.
- Marine railway dock.
- Ship lifts dry docks.
- Slip ways.

Dry or graving dock - A dry dock is also known as graving dock. It is long excavated chamber, having side walls, a semi circular end wall and a floor. The open end of the chamber is provided with a gate and acts as the entrance to the dock.

Floating dry dock - It may be defined as a floating vessel, which can lift ship out of water and retain it above water by means of its own buoyancy. It is a hollow structure made of steel or R.C.C consisting of two walls and a floor with the ends open.




To receive a vessel or ship for repair, the structure or floating dock is sunk to the required depth by filling water known as ballasting in its interior chambers and the vessel is then floated into position and berthed. The dock is raised bodily with the berthed vessel by a ballasting the chambers by pumping out the water. The earliest floating dry docks resembled the shape of ships

Marine railway dock - The marine railway or slip dock or slip way is an inclined railway extending from the shore well into the water as the off there. This railway track is used to draw out a ship needing repair out of the water.

<u>*Components of a marine dock*</u>

The essential parts of a marine dock are as follows:

- Cradle
- Track

Cradle - The cradle or platform is constructed of steel and moves up and down on an inclined track. The cradle is mounted on a system of rollers which move on the iron tracks laid on longitudinal timbers. These beams rest on piles and other firm foundations.

Track - The track consists of heavy rail sections secured to longitudinal sleepers supported on cross ties and laid at inclination varying from 1/12 to 1/25; usually an inclination of 1/15 is found convenient and useful.

Lift dry dock - This is a constructed platform capable of being lowered into and raised from water. Lowering and rising is achieved by means of hydraulic power applied through cylinders supporting the ends of cross girders carrying the platform.

Ship lifts - As the name suggests, in the ship lift, the ships are lifted bodily out of water. The ship lifts may be electric, hydraulic or pneumatic. These lifts are used for launching as well as for dry docking the ships. Their main advantage is the ease in adaptability to transfer system enabling multiple garaging of ships.

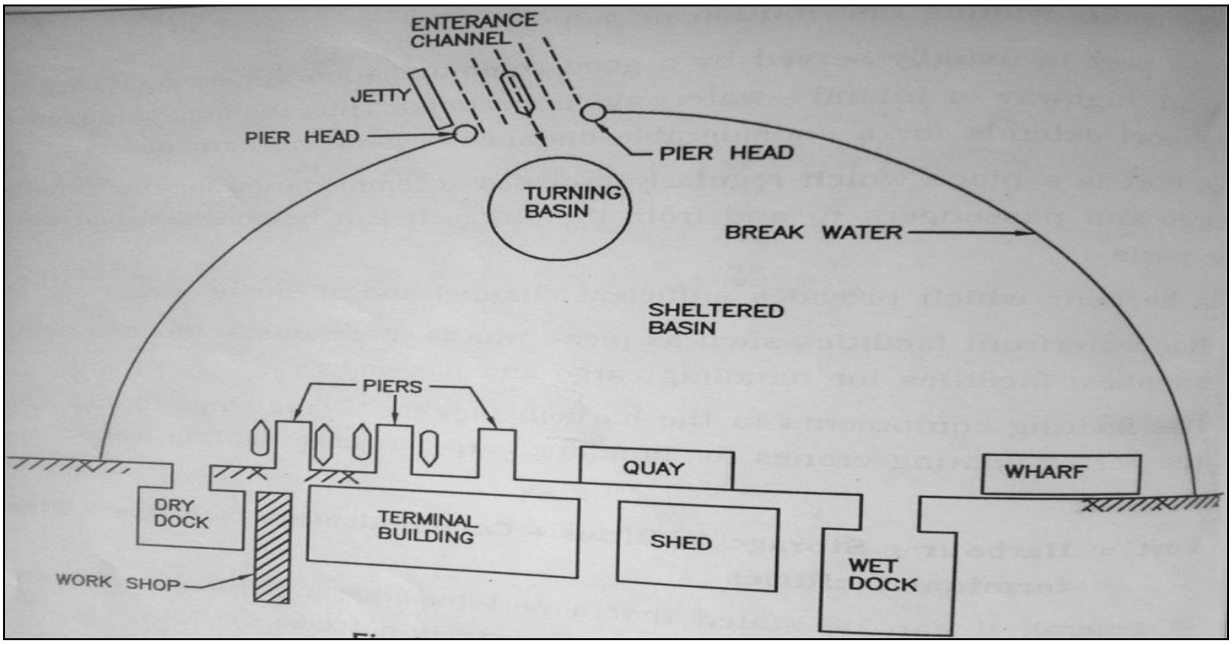
Slipways - This technique is used for repairs as well as for building of vessels. In its simplest form a slip way consists of an inclined path of timber or stone lay on a firm ground. On this inclined path a series of rails are fixed. The rails run up from a sufficient depth of water to the required height above the high water level to a point at which the longest vessel to accommodate is completely out of range of tide. The lower end of slip is tidal and open to water.

Requirements

- Approaches must be of sufficient depth and sheltered. In many cases approach channels both on the open coast and island docks have to be dredged frequently.
- Availability of fresh water to replace fouled and leaked water from docks.
- In inland to replace the fouled water from docks, separate canals from the rivers have to be provided, if alternate sources of water supply are not available. In case of sea coast docks, the sea water could be used for cleaning and replenishing the dock.

HARBOUR

It is partly enclosed area which provides safe and suitable accommodation for supplies, refueling, and repair, loading and unloading cargo.



Components of Harbour

1. Entrance Channel
2. Break Water
3. Turning Basin
4. Shelter Basin
5. Pier
6. Wharf
7. Quay
8. Dry Dock
9. Wet Dock
10. Jetty

Entrance Channel - Water area from which ships enter in the harbour and it should have sufficient width, 100 for small harbour, 100 to 160m for medium and 160 to 260m for large harbour.

Break Water - A protective barrier made up of Concrete or Course Rubble Masonry constructed from shore towards the sea to enclose harbour

Turning Basin - It is water area which is required for maneuvering the ship after entering to the harbour and it is large enough to permit free turning.

Shelter Basin - It is area protected by shore and breakwater.

Pier - It is a solid platform at which berthing of ships on both the sides are possible.

Wet Dock - Due to variation in tidal level, an enclosed basin is provided where in number of ships can be berthed. It has an entrance which is controlled by a lock gate.

Dry Dock - It is a chamber provided for maintenance, repairs and construction of ships. It includes walls, floor and gate.

Jetty - It is a solid platform constructed perpendicular to the shoreline for berthing of ships.

Quay - It is also dock parallel to the shore which is solid structure providing berthing on one side and retaining the earth on the other.

Wharf - It is a docking platform constructed parallel to shoreline providing berthing facility on one side only.

Site selection for a harbour

The guiding factors which playa great role in choice of site for a harbour is 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
- Availability of electrical energy and fresh water
- Favorable marine conditions
- Defense and strategic aspects

Requirements of good harbour

- This channels which may either be natural or artificial must have sufficient depth for the draft the vessels visiting the harbour
- The bottom should furnish secured anchorage to hold the ships against the force of high action.
- The land masses or breakwaters must be provided to protect against the destructive wave action.
- The harbour entrance should be wide enough to permit ready passage for shipping and at the same time, it should be narrow enough to restrict the transmission of excessive amounts of wave energy during storm.

Classification of harbour

1. Classification depending upon the protection needed
2. Classification depending upon the utility
3. Classification depending upon the location

Classification based on the protection needed

i. ***Natural Harbour***

Harbour protected by storms and waves by natural land contours, rocky out crops, or island that is called Natural Contour. Example - Kandla port, Cochin port & Mumbai Harbour

ii. ***Semi - Natural Harbour***

A semi – natural harbour is protected on the sides by the contours of land and requires manmade protection only to the entrance. Example - Mandvi, Veraval & Visakhapatnam port

iii. ***Artificial Harbour***

An artificial harbour is one which is manmade and protected from storms and waves by engineering works. Example - Chennai Harbour

Classification based on utility

i. ***Commercial Harbour***

It is a harbour in which docks are provided with necessary facilities for loading and unloading of cargo. Example - Chennai Harbour

ii. ***Refuge Harbour***

These are used as a heaven for ships in a storm or it may be part of a commercial harbour. Example - Chennai Harbour and Visakhapatnam Harbour

iii. ***Military Harbour***

It is a naval base for the purpose of accommodating naval ships or vessels and it serves as a supply depot. Example -Mumbai Harbour & Cochin Harbour

iv. ***Fishing Harbour***

These HARBOURs have facilities for departure and arrival of fishing ships. They have also necessary arrangement to catch fish.

Classification based on location

i. Ocean Harbour
ii. River Harbour
iii. Canal Harbour
iv. Lake Harbour

COASTAL PROTECTION STRUCTURES

The main and prime reason to construct coastal protection structures is to protect harbor and other infrastructures from sea wave effects such as erosion. Not only are they useful for changing current and sand movements but also to redirect rivers and streams.

Types of Coastal Protection Structures

There are various structures that considered or used as coastal protection structures for example groins, seawalls, bulkheads, break waters, and jetties. Description and advantages of these structures will be discussed in this article.

1. Seawalls

This large coastal protection structures can be built using different types of construction materials such as rubble mound, granite masonry, or reinforced concrete.

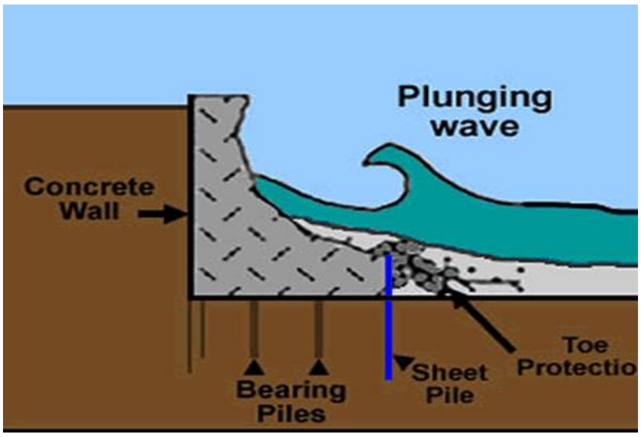
Seawalls are commonly built and run along shoreline to prevent coastal structures and areas from the detrimental influence of ocean wave actions and flooding which are driven by storms.

There are various arrangements or configurations that might be employed includes curved face seawall, stepped face seawall, rubble mound seawall. These forms will be explained in the following sections:

1.1 Curved face seawall

Curved face seawall is designed to withstand high wave action effects. Foundation materials loss, which might be caused by scouring waves and/or leaching from over topping water or storm drainage underneath the wall, is avoided by employing sheet pile cut off wall.

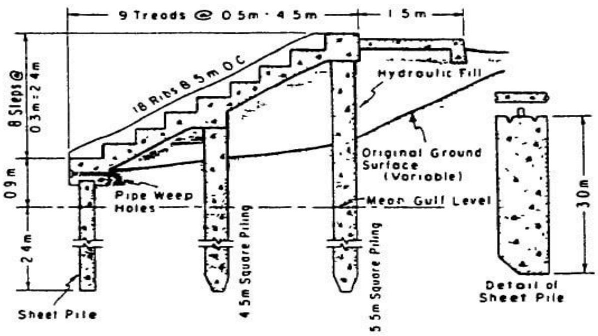
Moreover, the toe of the curved face seawall is built from large stones to decrease scouring. The Figure below show curved face sea wall with its components.



1.2 Stepped face seawall

Stepped face seawall is used to oppose or resist moderate wave actions. Reinforced concrete sheet piles with tongue- and- groove joints are employed to construction this type of seawall. The spaces which is created between piles is either filled with grout in order make sand proof cut off wall or install geotextile fiber at the back of the sheet pile to form sand tight barrier.

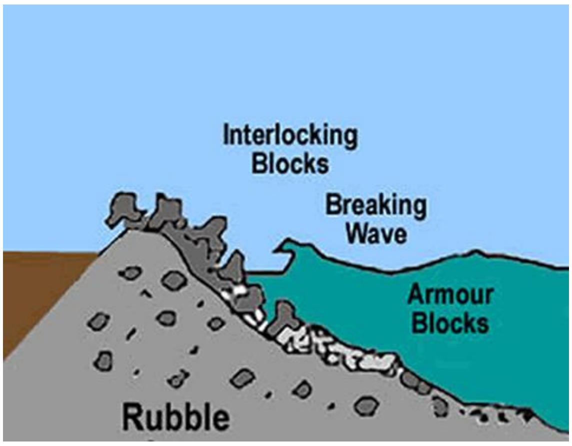
Applying geotextile is beneficial because it allows seeping water through and consequently prevents accumulating hydrostatic pressure. The Figure below shows stepped face seawall with the components and details.



1.3 Rubble Mound Seawalls

Design and construction this type of seawall configuration might be easier and cheaper. It can resist substantially strong wave actions. Despite scouring of the front beach, quarry stone comprising the seawall could be readjusted and settled without causing structural failure.

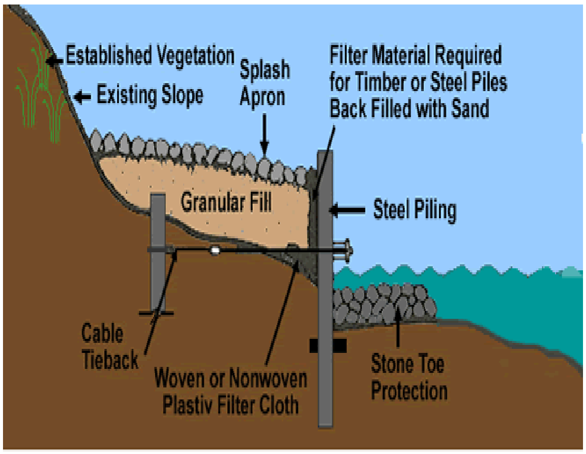
The Figure below provides components of rubble bound seawall. The rubble bound seawall dimensions are determined based on site conditions.



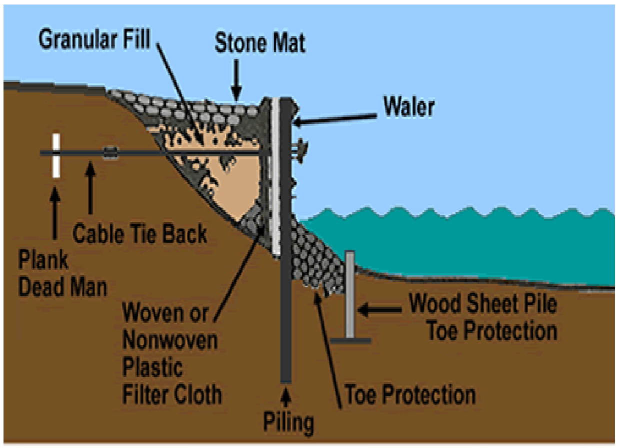
2. Bulkheads

Bulkheads can be constructed by concrete, steel, or timber. There two major types which are gravity structures and anchored sheet pile walls. The bulkheads might not have exposed to substantially strong wave actions and its main purpose is to retain earth but scouring at the base of the structure should be considered by the designer.

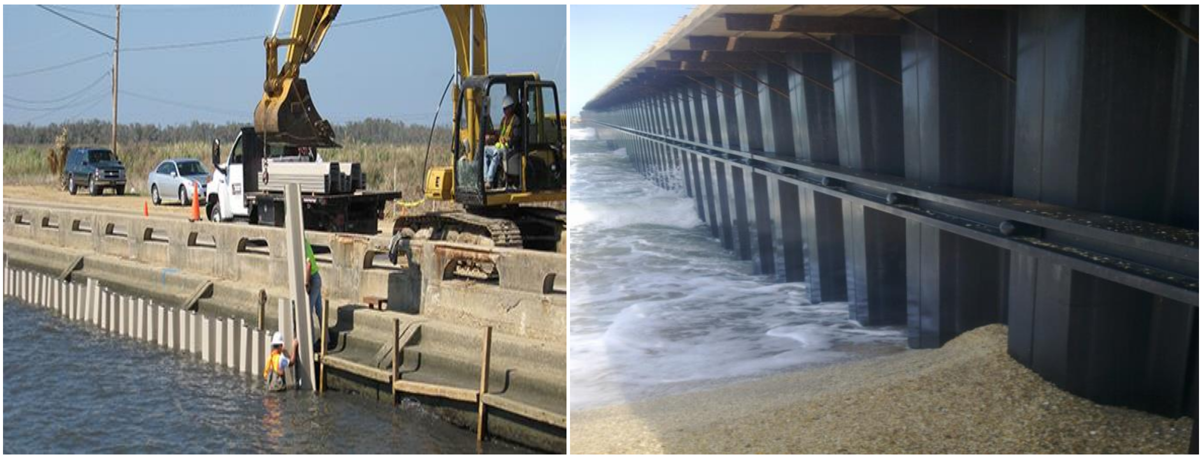
Cellular sheet pile bulkheads are employed for situations where rock is close to the surface and enough penetration cannot be achieved for the anchored bulkhead type. Moreover, sheet pile should be sufficiently reinforced for bending moment, soil conditions, hydrostatic pressures, and support points.



Steel Bulkhead



Timber Wall Bulkhead

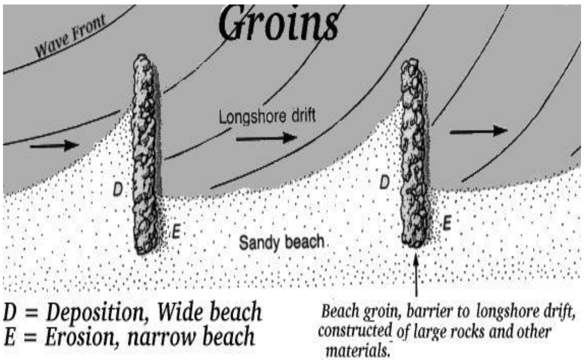


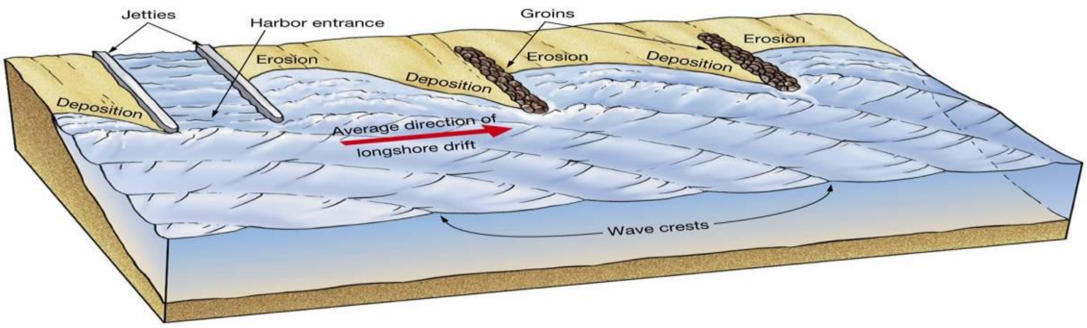
Sheet pile bulkhead

3. Groins

Groins are shore protection structures that decrease erosion affects to the shoreline by changing offshore current and wave patterns. Groins can be built by materials such as concrete, stone, steel, or timber and are categorized depend on length, height, and permeability.

Furthermore, groins are commonly constructed vertically to the shoreline and it can either impermeable or permeable.





4. Jetties

Jetties are usually built of materials such as concrete, steel, stone, timber, and occasionally asphalt used as binder. This structure is constructed at river estuary or harbor entrance and extended into deeper water to oppose forming of sandbars and limit currents.

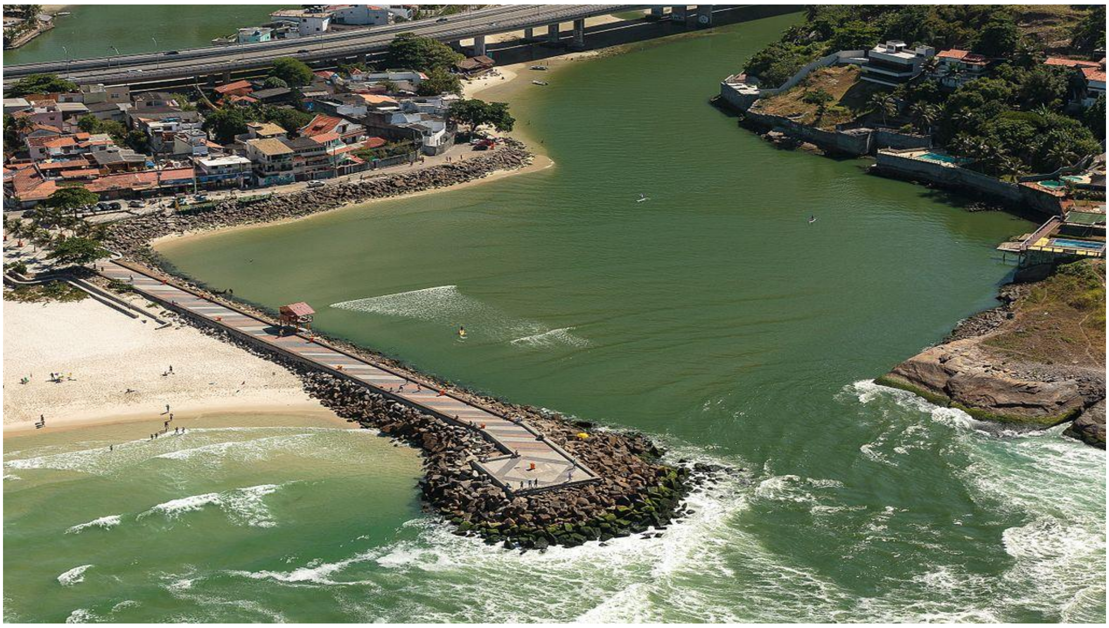

5. Breakwaters

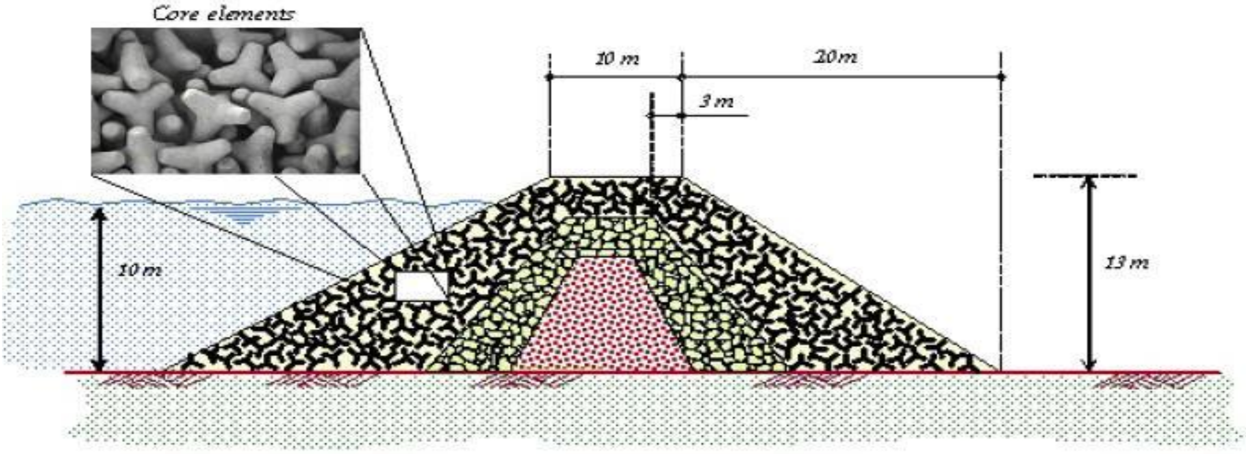
There are three major types of breakwaters namely: offshore, shore-connected, and rubble mound. Not only are they used to protect shore area, anchorage, harbor from wave actions but also to create secure environment for mooring, operating, and handling ships.

BREAKWATER

A breakwater is a structure constructed for the purpose of forming an artificial harbour with a basin so protected from the effect of waves as to provide safe berthing for fishing vessels. There are many different types of breakwaters; natural rock and concrete, or a combination of the two, are the materials which form 95 percent or more of all the breakwaters constructed. When a breakwater is to be built at a certain location, and the environmental impact of such a structure has already been evaluated and deemed environmentally feasible, the following parameters are required before construction can commence:

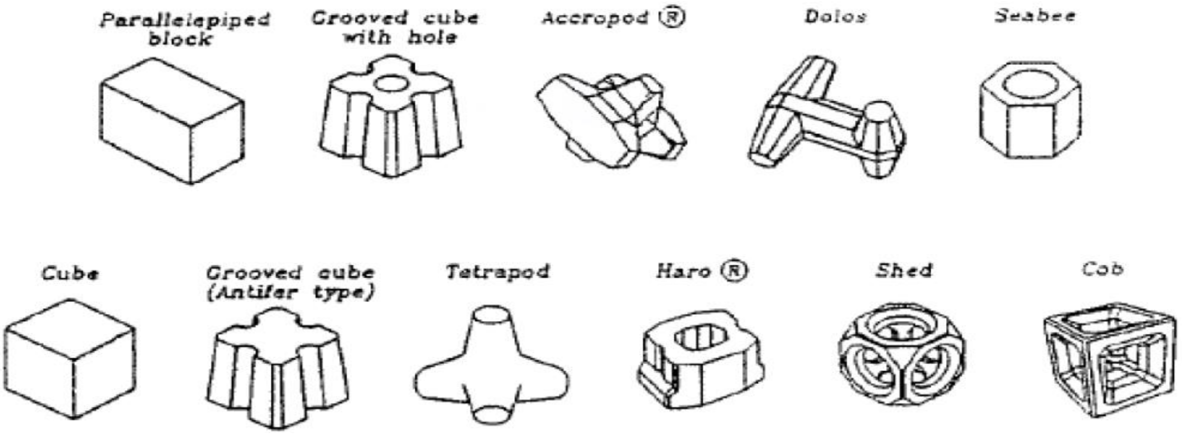
- A detailed hydrographic survey of the site;
- A geotechnical investigation of the sea bed;
- A wave height investigation;
- A material needs assessment; and
- The cross-sectional design of the structure.





Cross section of a breakwater

A view of breakwater showing the wave velocity inside harbor/port

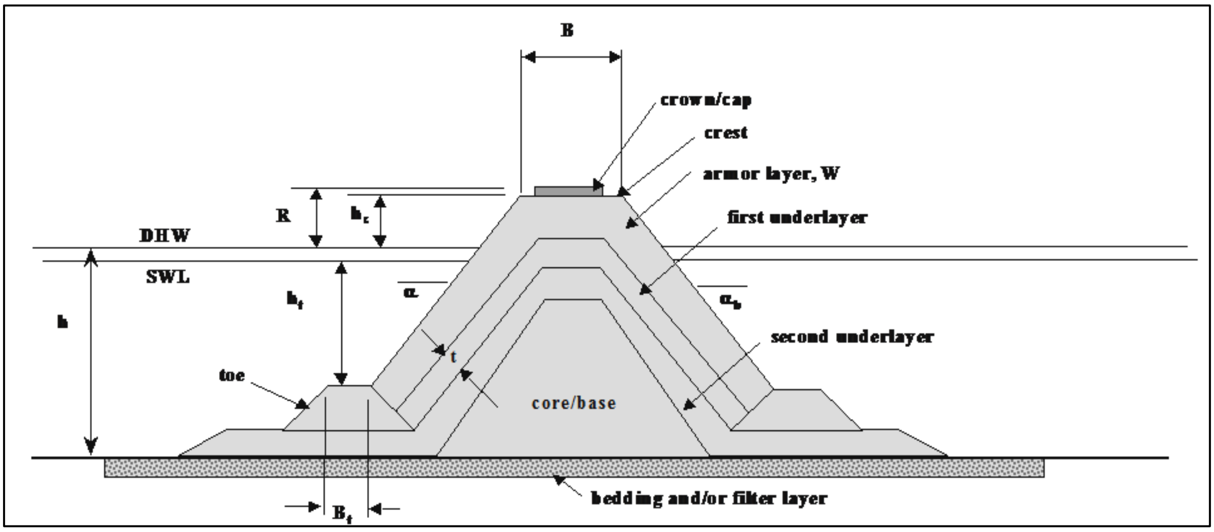


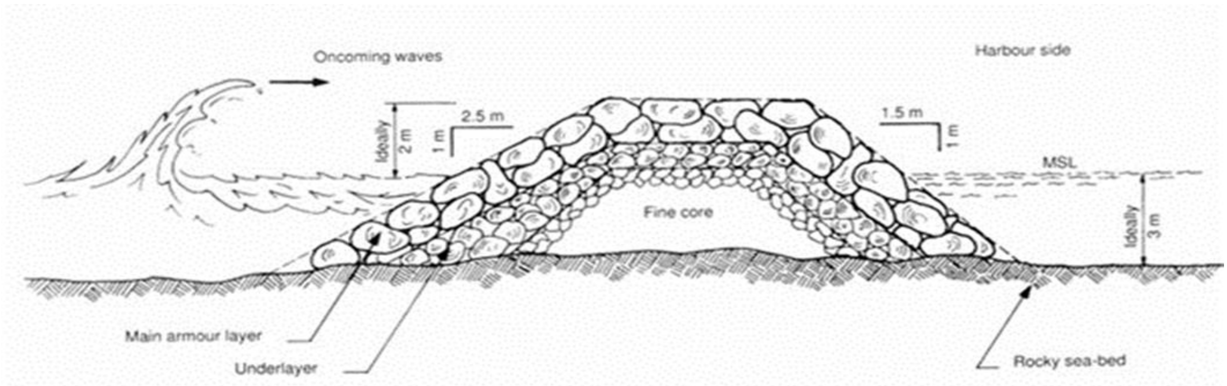
Types of concrete blocks in various shapes to construct breakwater

CLASSIFICATION BREAKWATERS

Rubble mound breakwater - A rubble mound breakwater normally consists of a core of small size rock covered with large [heavy] rocks or concrete elements. This outer layer is called the armour layer. An under-layer of rock is provided between the core and the armour layer.

- ➢ Outside layer large enough to resist wave action.
- ➢ Inside layer small enough to prevent removal of native fine material in between.






Advantages rubble mound breakwater

- ✓ Use of natural material
- ✓ Reduces material cost
- ✓ Use of small construction equipment
- ✓ Less environmental impact

- ✓ Easy to construct
- ✓ Failure is mainly due to poor interlocking capacity between individual blocks
- ✓ Unavailability of large size natural rocks leads to artificial armour blocks.

Disadvantages rubble mound breakwater

- x Needs a considerable amount of construction materials.
- x Continuous maintenance is required.
- x Sometimes there are difficulties in erection, as the rock weight increases with the increase of wave heights.
- x Can't be used for ship berthing

Vertical breakwater - A breakwater formed by the construction in a regular and systematic manner of a vertical wall of masonry concrete blocks or mass concrete, with vertical and seaward face.

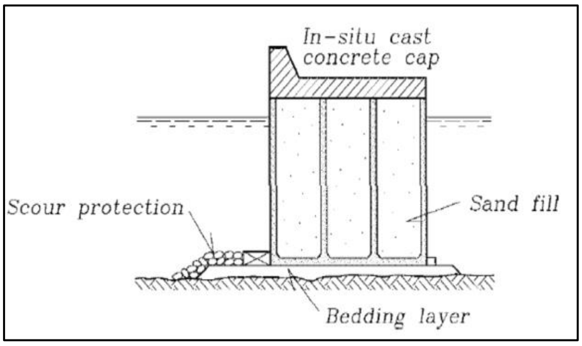
- ➢ Reflect the incident waves without dissipating much wave energy.
- ➢ Wave protection in port/channel
- ➢ Protection from siltation, currents
- ➢ Tsunami protection
- ➢ Berthing facilities
- ➢ Access/transport facility
- ➢ Normally it is constructed in locations where the depth of the sea is greater than twice the design wave height.

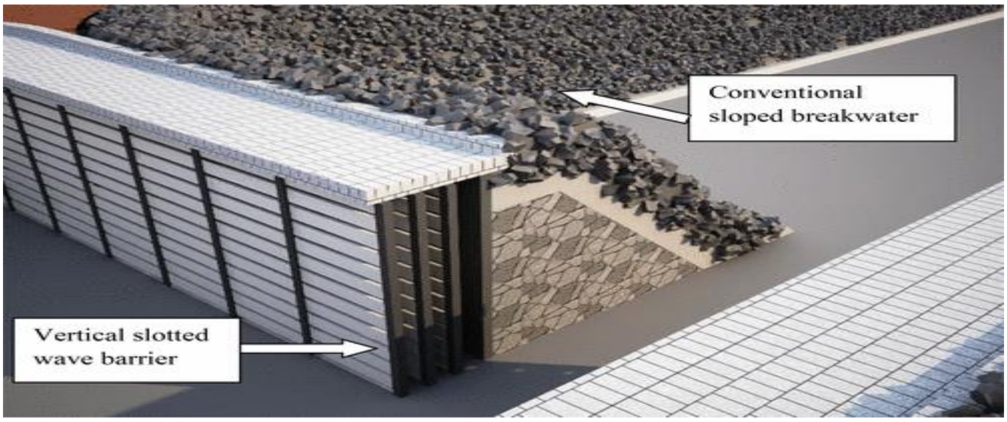
Types of vertical breakwater

1. Conventional type
2. Composite type

Conventional type

The caisson is placed on relatively thin stone bedding. The main advantage of this type is the minimum use of natural rock (in case scarce). Wave walls are generally placed on shore connected caissons (reduce overtopping)

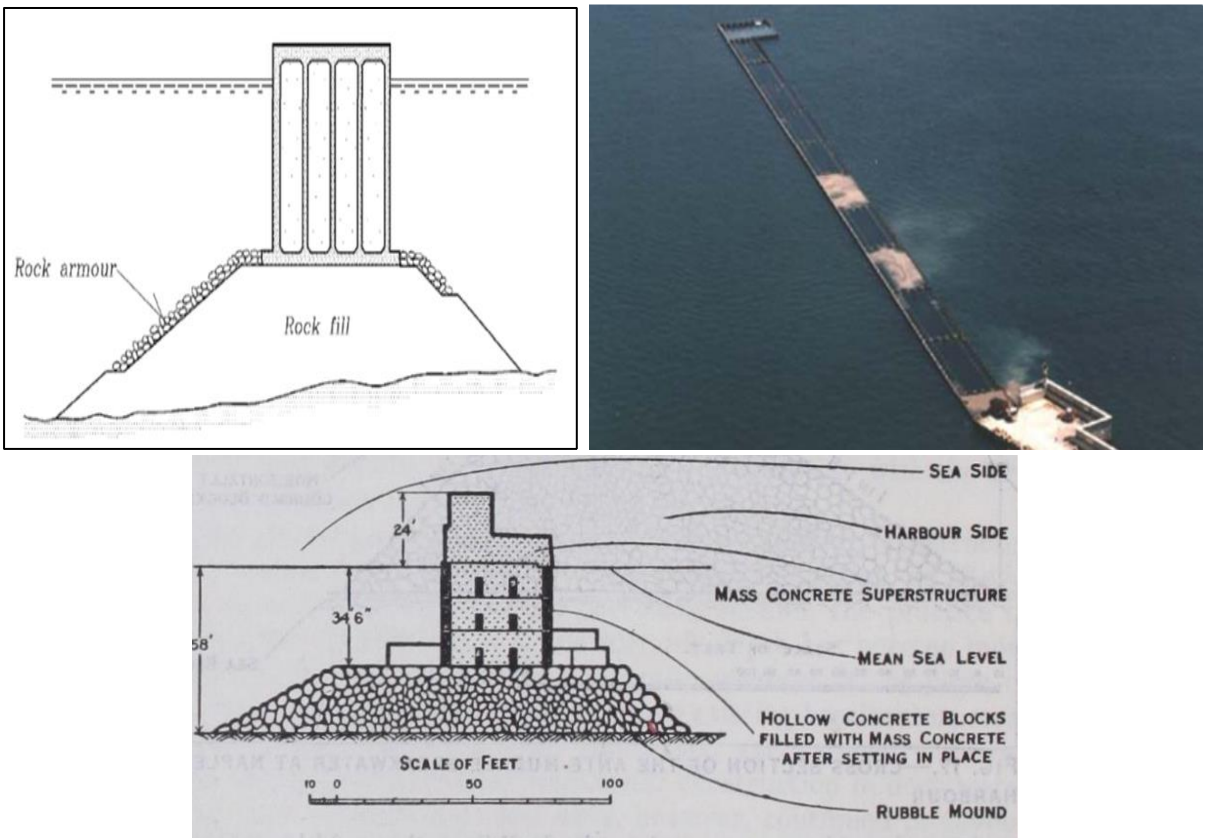




Conventional type

<u>*Composite type*</u>

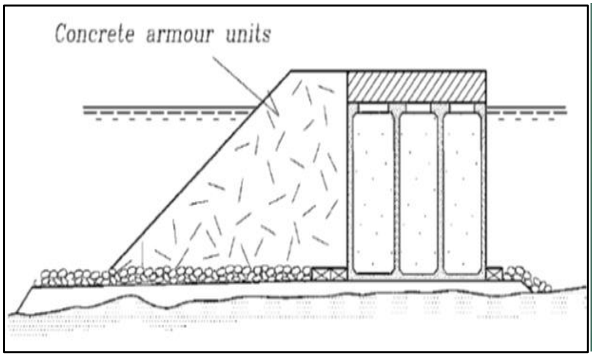
The caisson is placed on a high rubble foundation. This type is economic in deep waters, but requires substantial volumes of (small size) rock fill for foundation.



Composite type

<u>Horizontal composite type</u>

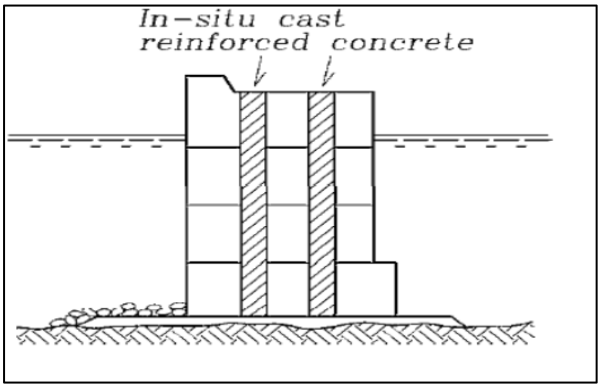
The front slope of the caisson is covered by armour units. This type is used in shallow water. The mound reduces wave reflection, wave impact and wave overtopping. Used when a (deep) quay is required at the inside of rubble mound breakwater.



Horizontal composite type

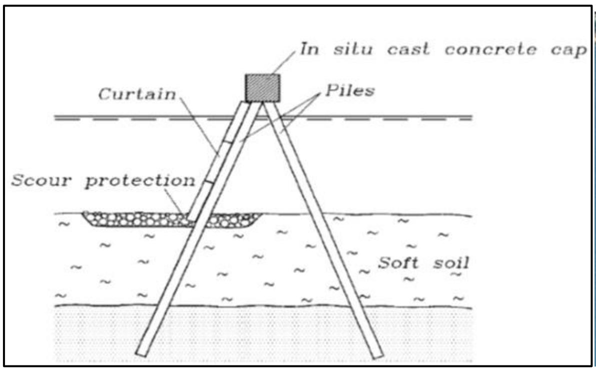
Block type

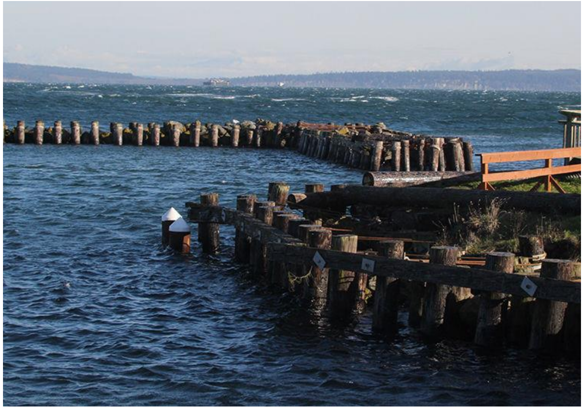
This type of breakwater needs to be placed on rock sea beds or on very strong soils due to very high foundation loads and sensitivity to differential settlements.



Piled breakwater with concrete wall

Piled breakwaters consist of an inclined or vertical curtain wall mounted on pile work. The type is applicable in less severe wave climates on site with weak and soft sub-soils with very thick layers.

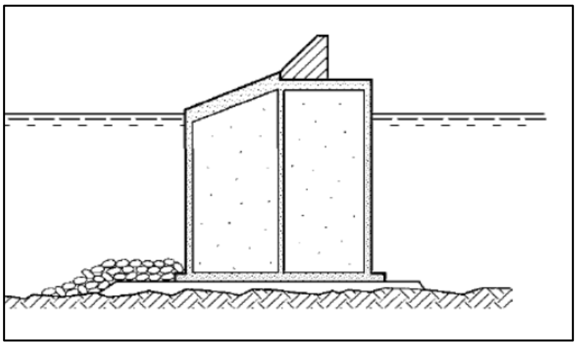


Piled breakwater with concrete wall

Sloping top breakwater

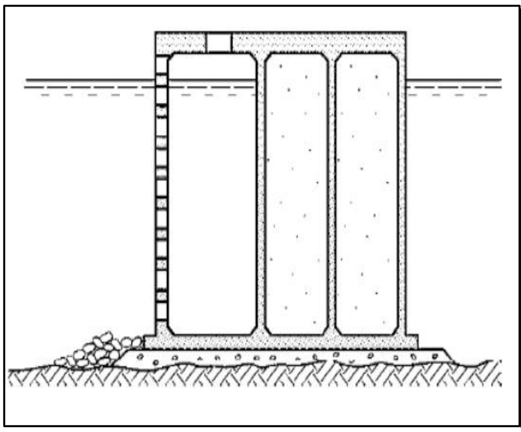
The upper part of the front slope above still water level is given a slope to reduce wave forces and improve the direction of the wave forces on the sloping front. Overtopping is larger than for a vertical wall with equal level.




Sloping top breakwater

Perforated front wall breakwater

The front wall is perforated by holes or slots with a wave chamber behind. Due to the dissipation of energy both the wave forces on the caisson and the wave reflection are reduced.




Perforated front wall breakwater

Disadvantages of vertical wall breakwaters

- Sea bottom has to be leveled and prepared for placements of large blocks or caissons.
- Foundations made of fine sand may cause erosion and settlement.
- Erosion may cause tilting or displacement of large monoliths.

- x Difficult and expensive to repair.
- x Building of caissons and launching or towing them into position require special land and water areas beside involvement of heavy construction equipments.
- x Require form work, quality concrete, and skilled labor, batching plants and floating crafts.

SIGNALS

For safe, efficient economic and comfortable travel of vessels in rivers, channels, harbors and along lake and ocean shores navigation aids are necessary.

Purposes

- To avoid dangerous zones
- To follow proper harbour approaches
- To locate ports during night and bad weather conditions

Requirements of signals

- Compels attention
- Permits time for easy response
- Commands respect
- Visibility distance

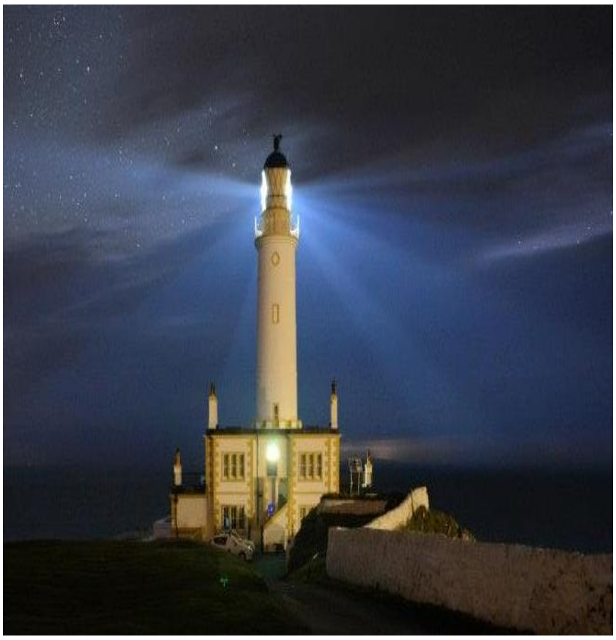
Types of signals

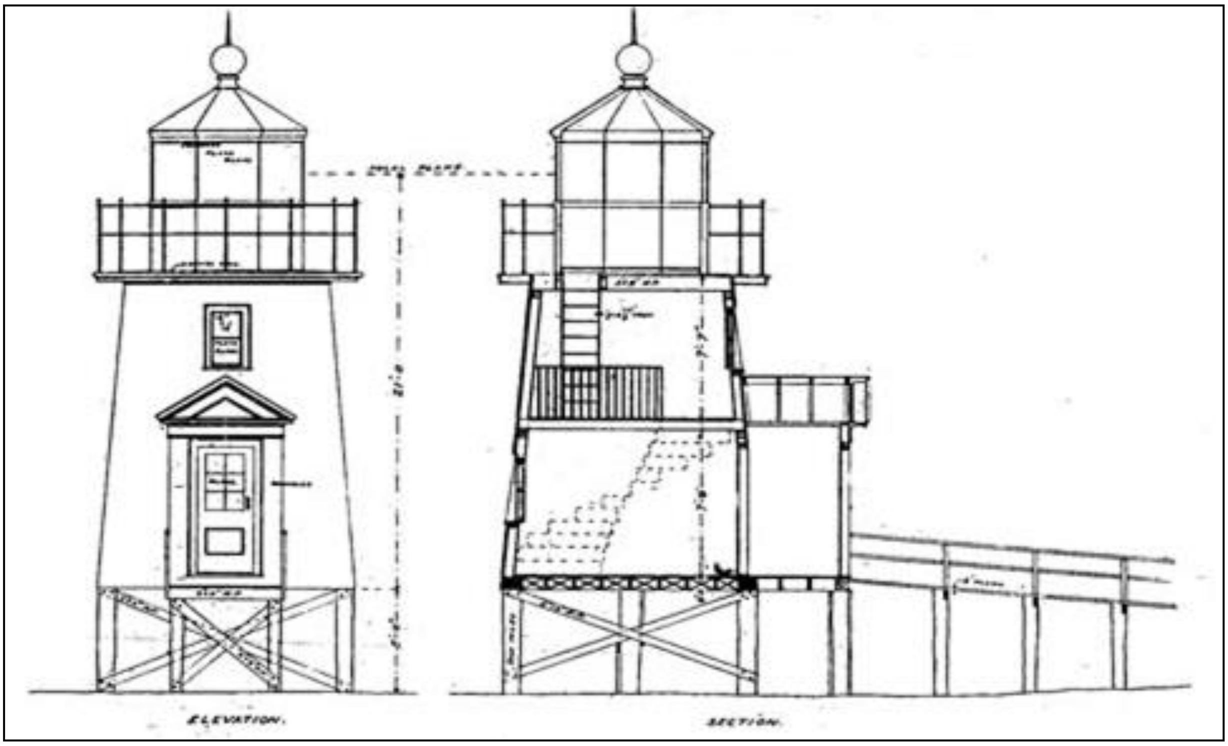
1. Fixed type
   - ❖ Light house
   - ❖ Beacon lights
   - ❖ Lights on piers
2. Floating type
   - ❖ Buoys
   - ❖ Lightship

FIXED NAVIGATIONAL AIDS

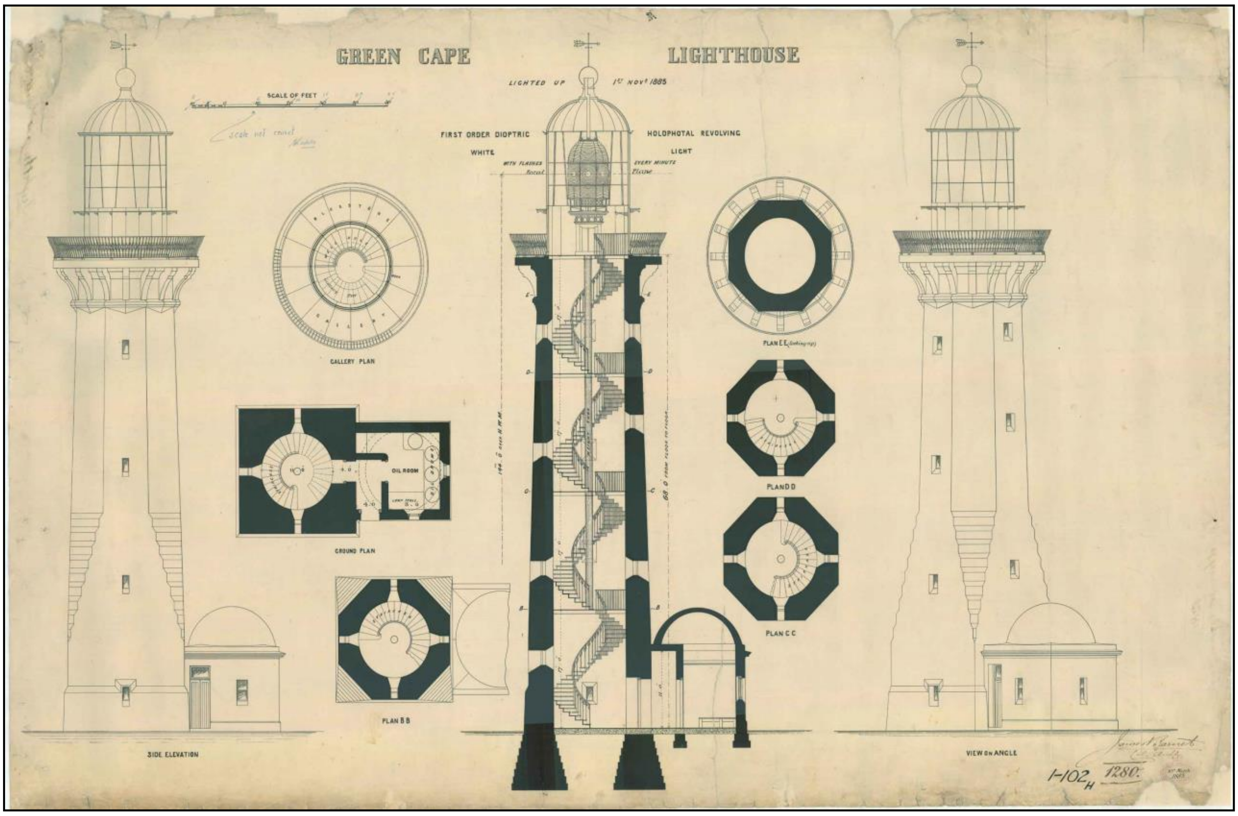
Light house

- ➢ They are all tower structure built of masonry or reinforced concrete.
- ➢ Beacon light is provided.
- ➢ Tower is divided into number of floors.
- ➢ The tower should be strong enough to with stand heavy wave action.
- ➢ Usually, they must have a visibility up to 30 km.





Rough layout of a lighthouse



An old layout of a Lighthouse

Beacon lights

- Beacon light are fixed or flashing for easy identification by the navigator.
- They are used for means of alignment or indicating changes of direction.

Beacon structure ***A Beacon light***

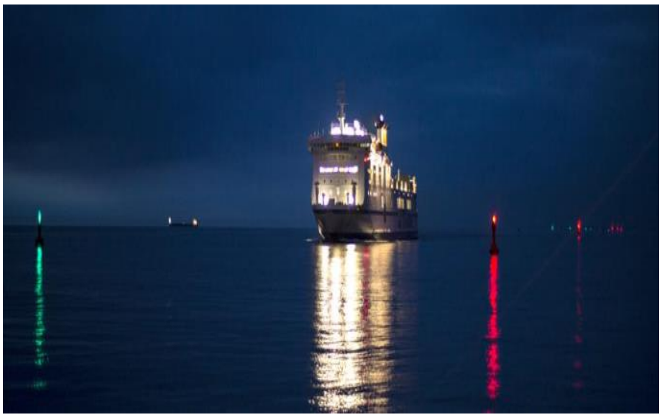
<u>FLOATING NAVIGATIONAL AIDS</u>

These are two types,

1. Buoys
2. Lightships

<u>Buoys</u>

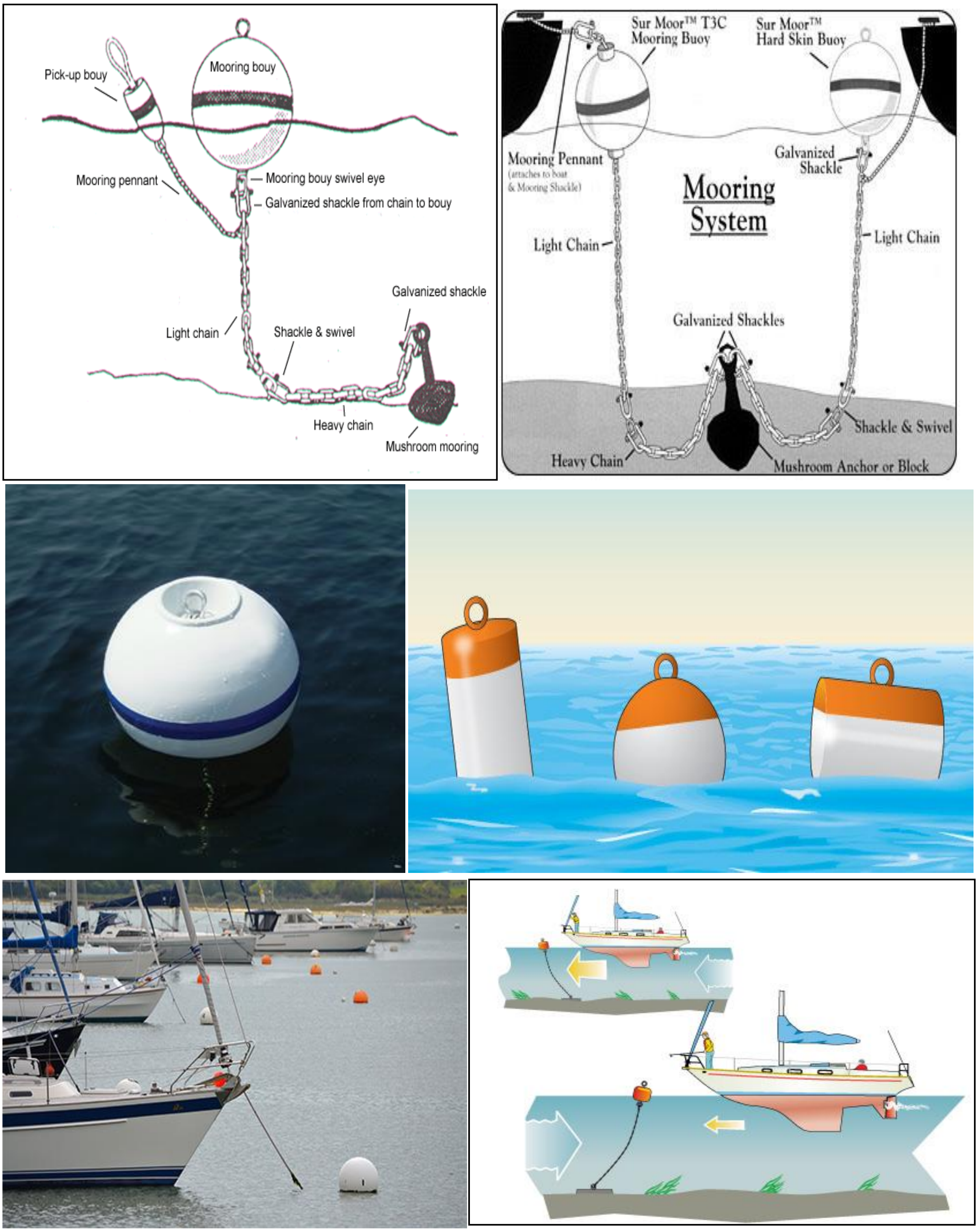
- They are small sized floating structures, generally in the form of large cylindrical cans and drums.



<u>Buoys are of different types</u>:

- Channel and entrance demarcation buoys
- Luminous buoys
- Audible buoys or bell buoys
- Mooring buoys

Types of buoys



Mooring Buoy

Lightships

- In locations where it is not practical to build light houses, small ships displacing about 500 tones are used for the purpose.
- The lantern is generally situated at about 9 to 12 m height above water levels.
- The bulls of lightships are generally painted with red color.
- They are generally held in position by a single anchor.

Lightships

INLAND WATER TRANSPORT

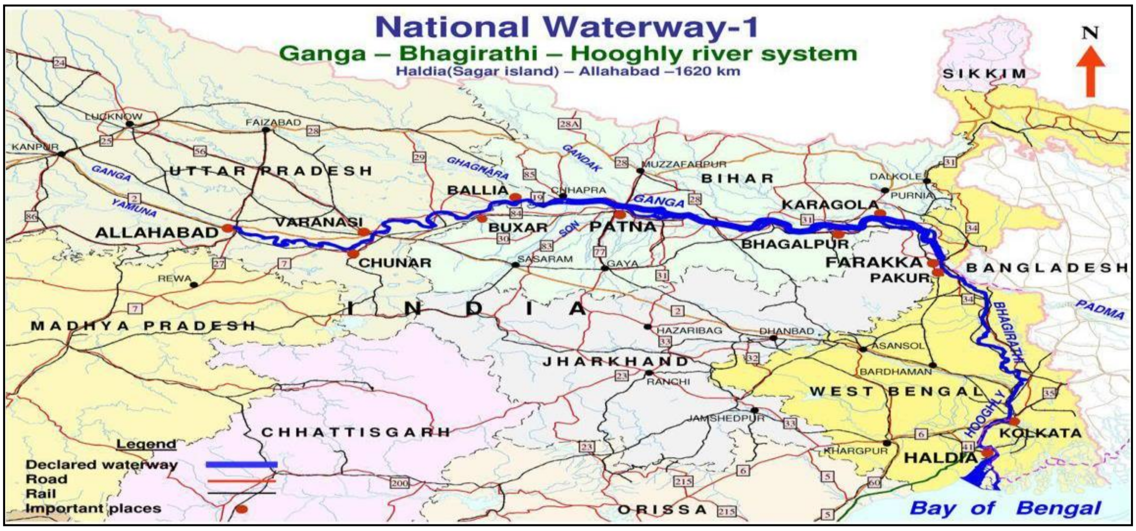
Inland Water Transport (IWT) has played an important role in Indian transport since ancient times. But due to the expansion of road and rail transport, the importance of this mode has declined considerably. The potential of IWT to encourage and support economic and social development is huge, more so in a developing nation where resources are scarce.

India has inland waterways with a navigable length of 14,500 km, but of this only 5,700 km is being used for navigation by mechanized vessels. IWT, accounts for less than a 1% share of goods transported within India. The Government aims to develop IWT as a complementary service in a multi-modal transport network.

The Inland Waterways Authority of India (IWAI), created in 1986 is responsible for development and regulation of inland waterways for shipping and navigation. The Inland Waterways Authority of India Act, 1985 empowers the Government to declare waterways with potential for development of shipping and navigation as National Waterways and develop such waterways for efficient shipping and navigation. **Five** national waterways have been declared so far. Study these maps carefully. You should know the given NW passes through which state, major rivers involved etc.

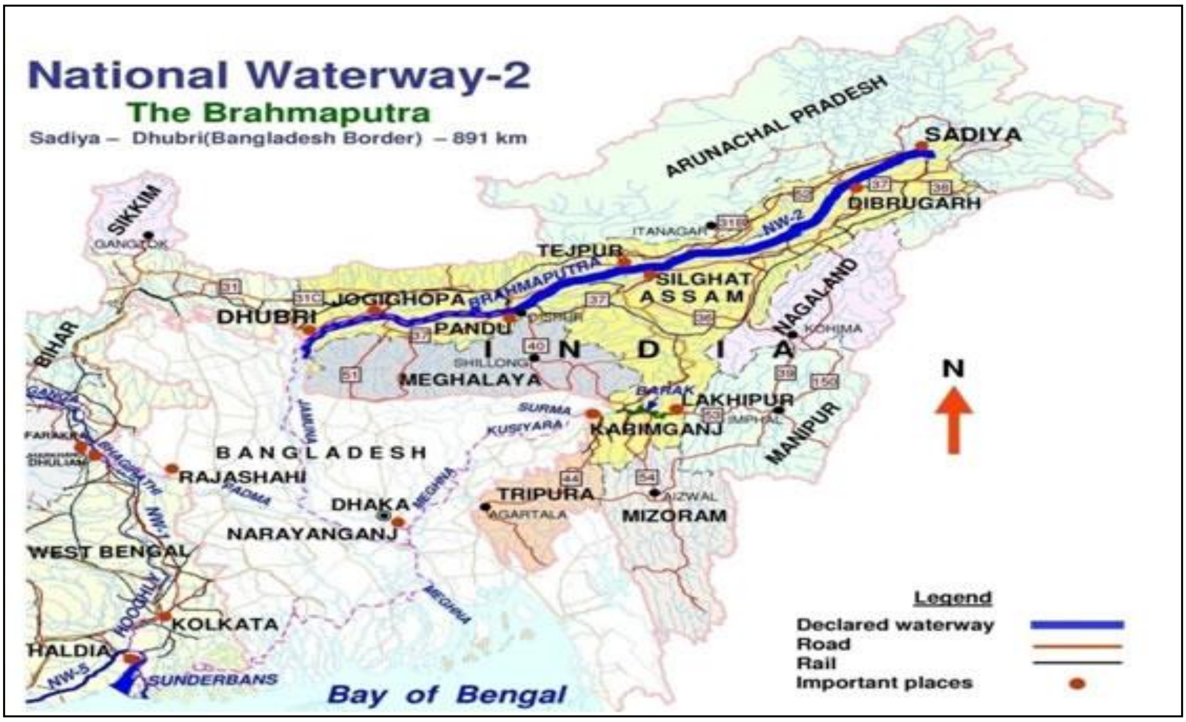
National Waterway No 1 (NW-1) - The Ganga (North India)

The Ganga-Bhagirathi-Hooghly River System connecting Haldia-Kolkatta (Calcutta) - Farakka - Munger - Patna - Varanasi - Allahabad. The NW-1 stretches to more than 1620 Kms of potentially navigable waterways. River conservancy works, dredging, day channel marking and bandalling are carried out on a year-to-year basis. Provisions for 1.5 - 2m depth channels, night navigational facilities are in the process of implementation.



National Waterway No 2 (NW-II) - The Brahamaputra (North-East India)

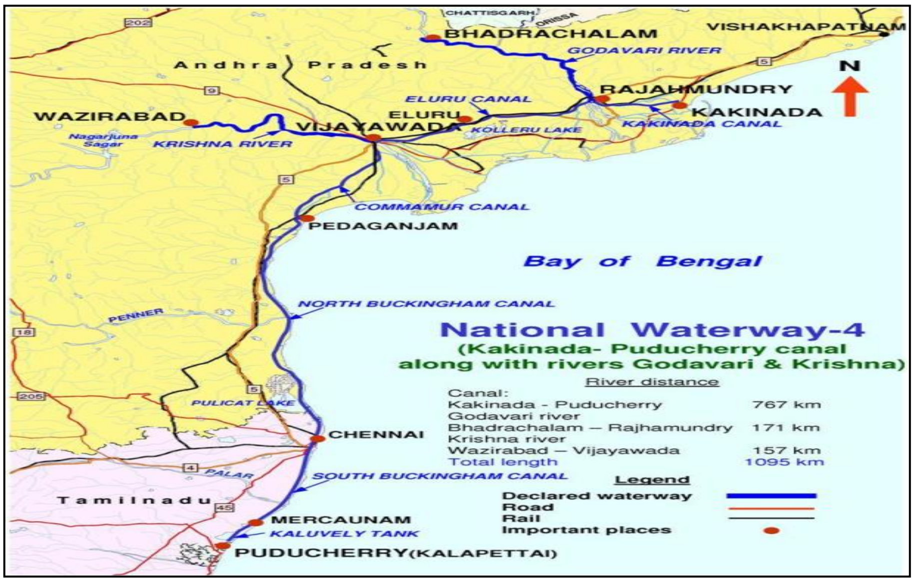
The river Brahmaputra connecting Dhubri-Pandu (Guwahati)-Tezpur-Neamati-ibrugarh-Sadiya stretching to about 891 Kms was declared a National Waterway in the year 1988. River conservancy works, dredging, day channel marking and bandalling are carried out on a year-to-year basis. Provisions for 2-meter depth channels, night navigational facilities are under consideration. An inland Water Transport transit and trade protocol exists between India and Bangladesh. The NW-2 connects the North East region with Calcutta and Haldia ports through Bangladesh and Sunderbans waterways.



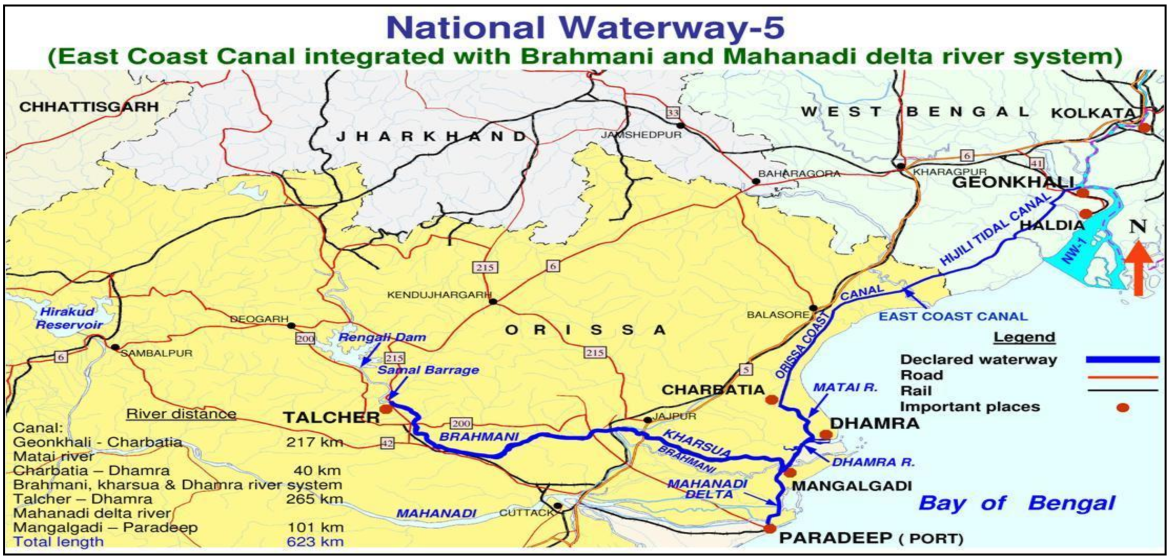
National Waterway No 3 (NW-III) - The West Coast Canal (South West India)

The West Coast Canal located in Gods Own Country - Kerala runs from Kollam to Kottapuram and was declared a National Waterway in 1993.The dredging of this canal has been finished. The NW-3 is one of the most navigable and tourism potential area in India and has much to offer to the potential tourist.

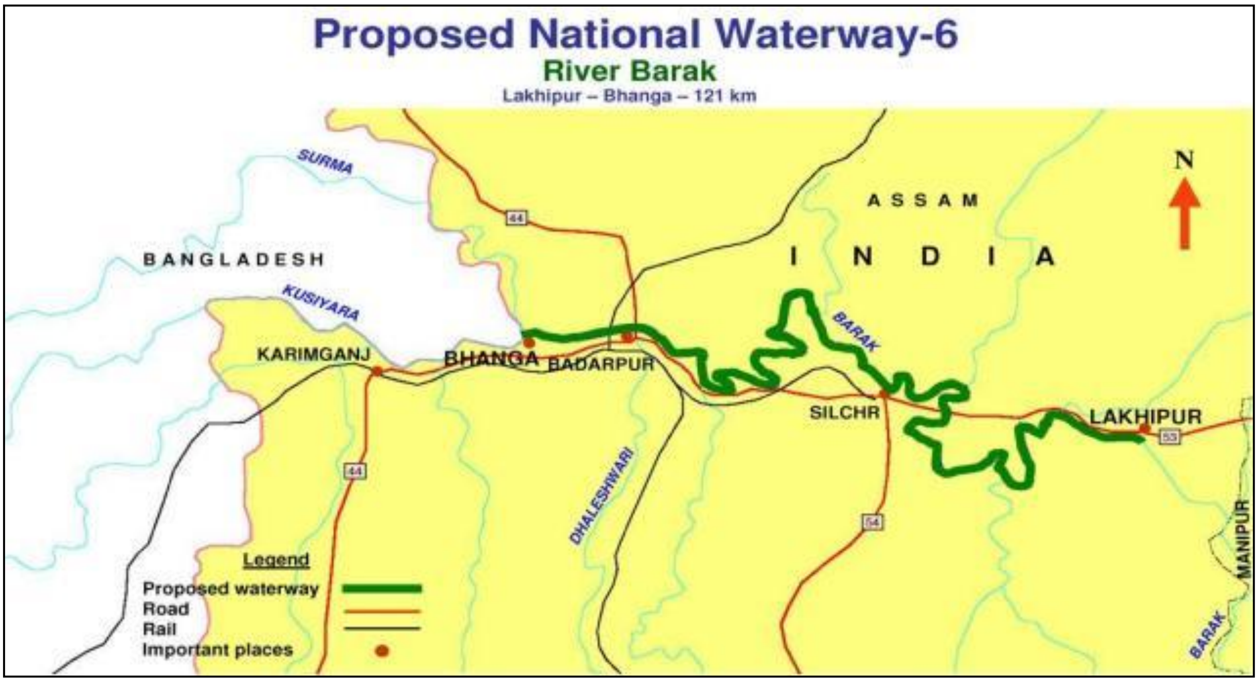
NW-4 – Kakinada-Puducherry stretch of Canals and the Kaluvelly Tank, Bhadrachalam-Rajahmundry stretch of river Godavari and Wazirabad- Vijayawada stretch of river Krishna – 1078 km



NW-5 – Talcher-Dhamra stretch of rivers, Geonkhali-Charbatia stretch of East Coast Canal, Charbatia-Dhamra stretch of Matai river and Mahanadi Delta rivers (588 km)



The National Waterway (Lakhipur-Bhanga Stretch of the Barak River) Bill, 2013 was introduced in the Rajya Sabha in 2013. The Bill proposes to declare and develop the 121km long Lakhipur-Bhanga stretch of the Barak river in Assam as National Waterway 6 – NW-6.



Proposed National Waterway

Benefits of IWT

- ✓ Low capital cost and operating costs
- ✓ Low maintenance cost

- ✓ Least energy consumption – highly fuel efficient mode of transport.
- ✓ Least impact on environment among other modes of transport – low carbon emissions.
- ✓ Enormous capacity reserves to carry bulk cargo, coal etc
- ✓ Can provide access to far flung areas - North Eastern states **now receive coal, food grains** through IWT.

<u>Constraints in development of IWT</u>

- x Diversion of river water for irrigation – Volume of water in the rivers has lessened on account of construction of canals for irrigation purposes.
- x Deforestation of hill ranges leading to erosion, accumulation of silt in rivers.
- x Insufficient depths throughout the stretch of navigable waters. For example, the peninsular rivers depend on rainfall for their volume of water. During dry season, navigation is difficult.
- x Most of the large rivers of the country enter the sea through shallow sand choked delta channels. Thus navigation is hampered unless dredging is done.
- x Non availability of adequate navigational aids resulting in unsafe passage and high travel time.
- x Lack of adequate terminal facilities at the loading and unloading points.
- x Lack of investment for the creation of infrastructure, modernization and lack of efficient operators.
- x Fuel cost is another factor. The barges run on high-speed diesel, the same fuel used by trucks. If diesel prices soar, it will be disadvantageous.
- x Environmentalists have criticized the move to construct dams for promoting IWT as it will have an adverse impact on the ecology.

CONTAINER TRANSPORTATION

Shipping is a service industry that generally provides cargo transportation of international trade. Approximate 90% cargo volume of international is transported by sea. Often, the shipping industry is categorized into two major sectors:
(1) The bulk shipping which provides services mainly in the transportation of raw materials such as crude oil, coal, iron ore, and grains; and
(2) The liner shipping which provides services in the transportation of final and semi-final products such as computers, manufacturing product and other consumption goods.
Cargo carried by liner shipping has come to be known as general cargo. Liner shipping is to provide regular services between specified ports according to time-tables and prices advertised well in advance. The service is, in principle, open to all shippers and in this sense it resembles a public transportation service. The provision of such a service, often offering global coverage, requires extensive infrastructure in terms of ships, agencies, and equipment.

The vast majority of liner cargo is containerized –that is, it is carried in sealed metal containers from point of origin to destination. These containers come in standard sizes (typically 20’, 40’, and 45’ in length) and may include various specialized technologies, such as refrigeration units for chilled and frozen foods, or internal hanger systems for carrying garments. Containers serve, in essence, as a packing crate and in-transit warehouse for virtually every type of general cargo moving in international commerce. The standard measure of the volume of containerized cargo is a TEU (twenty-foot equivalent unit).

Containers move along a network of nodes and links. The nodes are physical locations where container movement is interrupted and/or containers are handled. Many of these concern multimodal transfer points where containers are transferred from one mode to another. The links between nodes are characterized both by a mode of transport (road, rail, inland waterway) and a supporting infrastructure (roadway, canal/river, railroad track, rail marshalling yard, etc.). As containers move along this network they can either be empty, loaded with a single consignment (Full Container Load, FCL) or loaded with multiple consignments (Less-than Container Load, LCL).

The Containerized cargo moves from inland point to inland point via a multi-modal network linking vessels, port terminals, trucks and trains. At the heart of this service network is the planning, tracking and delivery of cargo and state-of-the-art information systems needed to provide certainty and reliability to shippers.