INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

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COURSE- BTECH BRANCH: CIVIL ENGINEERING

SEMESTER 6TH CHAPTER NAME: RAILWAYS UNIT 1

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1.1 ROLE OF RAILWAY IN TRANSPORTATION:

Since its inception, Indian Railways has successfully played the role of the prime carrier of goods and passengers in the Indian subcontinent. As the principal constituent of the nation's transport infrastructure, the Railways has an important role to play.

a) It helps integrate fragmented markets and thereby stimulate the emergence of a modern market economy.

b) It connects industrial production centres with markets as well as sources of raw material and thereby facilitates industrial development.

c) It links agricultural production centres with distant markets as well as sources of essential inputs, thereby promoting rapid agricultural growth.

d) It provides rapid, reliable, and cost-effective bulk transportation to the energy sector; for example, to move coal from the coalfield to power plants and petroleum products from refineries to consumption centres.

e) It links people with places, enabling large-scale, rapid, and low-cost movement of people across the length and breadth of the country.

f) In the process, Indian Railways has become a symbol of national integration and a strategic instrument for enhancing our defence preparedness.

g) Railways make it possible to conduct multifarious activities like business, sight seeing, pilgrimage along with transportation of goods.

h) It is suitable for long distance travel.

i) Plays an important role in national integration.

j) Railways bind the economic life of the country.

k) It accelerates the development of the industry and agriculture.

l) Today the railways have become more important than all other means of transport put together.

1.2 HISTORICAL DEVELOPMENT OF RAILWAYS:

1831–33 The first idea of a railway line from Madras (now Chennai) to Bangalore conceived to improve the transport system of southern India.

1843 Lord Dalhousie considers the possibility of connecting India by means of railways.

1844 Mr R.M. Stephenson forms the East Indian Railway Company for construction of railway lines.

1845–46 Trial survey of a new line from Calcutta (now Kolkata) to Delhi
1848–49 Construction of a railway line from Howrah to Raniganj sanctioned.
1850 Construction of a railway line from Bombay to Thane started by the Great Indian Peninsula Railway Company.

1851 Work started for a railway line between Bombay and Kalyan on 31 October.

1853 First railway line from Bombay to Thane opened for passenger traffic for a distance of 21 miles (34 km) on 16 April.

1854 Railway line between Howrah and Hoogly (24 miles) opened for passenger traffic on 15 August.

1856 Railway line between Veyasarpady and Waljah road (63 miles) opened for traffic under the banner of Madras Railway Company. In fact, this was the first proposal initiated in 1831 but could be completed only in 1854.

1856 First train in South India from Royapuram to Waljah road (Arcot).

1866 Calcutta linked with Delhi, Amritsar, and Bombay

1850–68 First stage of development of Indian Railways classified as the Early Guarantee System. The Government guaranteed a minimum percentage of return to shareholders in order to attract private enterprises to construct railways, but retained the right to purchase these railways at the end of 25 or 50 years.
A number of railway companies were formed for the construction of railways, namely, East India Railway (EIR), Great Indian Peninsula Railway (GIP), Bombay, Baroda, and Central India Railway (BB&CIR) and Madras State Railway (MSR), etc.

1869–81 In 1869, it was decided by the British Government that future railway projects should be either under the new guarantee system or under stateowned railways. Few states started construction of railway lines separately.
The Government, however, exercised a considerable measure of control to commercialize them. At this time there were company-managed railways under the new guarantee system as well as state-managed railways.
After 1870 the railways developed very fast.

1871 Introduction of metric gauge in India on account of its being cheap and Economic

1873 First metre gauge line opened from Delhi to Farukanagar

1881 First hill railway (Darjeeling Himalayan Railway; narrow gauge) Inaugurated

1887 Victoria Terminus railway station constructed in Bombay

1891 Toilets introduced in third class coaches

1903 96-km-long Kalka–Shimla narrow gauge line opened to traffic on 9 November

1905 Railway Board assumes office; established with one president and two Members

1922 Railway Board reconstructed and given a free hand with extra powers

1924 Railway finances separated from general finances

1924 Railway Board reconstituted with the chief commissioner as the president, an ex-officio secretary to the Government of India, and two members

1925 As a general policy to assume control over company railways, the Government took over the management of East India Railway and Great India Peninsula Railway

1925 First railway line electrified, consisting of the harbour branch line of GIP

1928 BB&CI Railway electrified its Bombay Suburban section

1929 Electrification of the entire section from Bombay VT to Pune completed on 5 November

1930 Central Standards Office (CSO) under Chief Controller of Standardization set up to standardize all equipment commonly in use by the Railways

1930 Indian Railways stretched over 66,300 route km

1931 Madras suburban section electrified

1930–31 There was general economic depression and a sum of Rs 110 million was withdrawn from the Railways reserve fund and credited to general Revenues

1931 Electrification of double track from Madras Beach to Tambaram and of sidings at Madras Beach, Madras Egmore, and Tambaram stations completed on 2 April; first electric train started running on 11 May

1931 Suburban services between Madras Beach and Tambaram converted to electric traction on 1 August

1936 Air conditioning introduced in passenger coaches

1937 Burma separated from India and about 3200 km of railway lines taken out of Indian Railways

1939–42 During the second world war, the Indian Railways was called upon to release track material, locomotives, and wagons for construction of lines in the Middle East. This resulted in the closing down of 26 branch lines. Railway workshops were used for manufacture of defence material. At the end of the war, there were heavy arrears for the renewal and replacement of various assets

1942 War Transport Board formed

1947 India became independent; due to partition of the country, railway lines and assets divided between India and Pakistan

1947 Immediately after independence, the Railway Board consisted of five members including a chief commissioner and financial commissioner

1947–51 At the time of independence, there were 42 railway systems consisting of 13 class I railways, 10 class II railways, and 19 class III railways. These included 32 lines owned by ex-Indian states. The Government of India decided to rationalize these railways to improve efficiency and facilitate better management.

1950 Production of steam locomotives started in Chittaranjan Locomotive Works

1952 Railway Staff College, Vadodara, set up

1952 Railway Testing and Research Centre (RTRC) set up

1952 Integral Coach Factory (ICF), Madras, set up as a production unit for all welded steel, lightweight integral coaches

1954 Position of chief commissioner for Railways renamed as chairman of Railway Board

1955 Indian Railway Institute for Civil Engineering, Pune, set up

1951–56 During the first Five Year Plan, there was special emphasis on rehabilitation and replacement of the assets overstrained and totally neglected during World War II. A sum of Rs 2570 million was allotted to Indian Railways out of a total plan expenditure of Rs 23,780 million

1956–61 During the second Five Year Plan, the focus was on the development of rail transport capacity to meet the requirement of movement of raw materials and goods. A sum of Rs 8960 million (18.7%) was allotted to Indian Railways (IR) out of a total plan expenditure of Rs 48,000 million.

1957 Indian Railway Institute for Signal and Telecommunication, Secunderabad, set up

1957 Research Design and Standards Organisation (RDSO), Lucknow, set up after the merger of various standards committees and RTRC

1957 IR decides to adopt a 25-kV, 50-cycle, single-phase, ac system for Electrification

1957 Railway Protection Force (RPF) constituted

1959 Post of Member Mechanical created in the Railway Board

1961 Diesel Locomotive Works (DLW) set up at Varanasi; Chittaranjan Locomotive Works (CLW) started manufacture of electric locomotives

1961–66 The strategy adopted in the third Five Year Plan was to build up an adequate rail transport capacity to meet the traffic demands. It was proposed that this should be done through modernization of traction, i.e., by switching from steam traction to diesel or electric traction in a progressive manner. Track technology and signalling were also improved to match the new traction system. During the third Five Year Plan, a sum of Rs 8900 million (11.9%) was allotted to Indian Railways out of a total grant of Rs 75,000 million.

1966–69 There was a gap of three years between the third Five Year Plan and the fourth Five Year Plan as the Government wanted to review the results of the preceding development plans and adjust its strategy accordingly.

1969 Divisional system uniformly adopted by Indian Railways

1969 New Delhi–Howrah Rajdhani Express running at a speed of 120 km/h Introduced

1969–74 The fourth Five Year Plan was drawn with a renewed emphasis on the twin objectives of modernization of the Railways and improving the operational efficiency of the system by more intensive utilization of the existing assets of the Railways. A sum of Rs 10,500 million (6.6%) was allotted for the development of the Railways out of a total of Rs 159,000 million

1974 Rail India Technical and Economic Services (RITES) formed

1976 Indian Railway Construction Company (IRCON) formed

1974–78 The main emphasis of the fifth Five Year Plan was on the development of a rapid transport system in metropolitan cities, improvement in financial viability through cost reduction techniques, resource mobilization, optimum utilization of assets, and achievement of national self-sufficiency in railway equipment.
A sum of Rs 22,000 million (5.6%) was allotted to the Railways out of a total of Rs 393,000 million

1982 The Railway Reforms Committee recommends four additional zones after studying the efficiency bureau reports of 1954, 1961, and 1965 on the existing nine zones

1984 First Metro rail introduced in Kolkata

1980–85 The sixth Five Year Plan was drawn up in the face of anticipated resource constraints and a heavy backlog of arrears of renewal of assets such as wagon and tracks. The main plan was that the limited resources of the Railways would be used for the rehabilitation of assets. A sum of Rs 51,000 million was allotted to the railways out of a total of Rs 975,000 million for all the public sector undertakings for the entire plan period.

1985–90 The seventh Five Year Plan provided an outlay of Rs 123,340 million. Freight traffic in the terminal year of the plan, namely, 1989–90, was estimated to reach a level of 340 million tonnes.

1985 Computerized Passenger Reservation System introduced

1987 Rail Coach Factory (RCF) established at Kapurthala

1988 First Shatabdi train introduced between New Delhi and Jhansi

1988 Container Corporation of India (CONCOR) established

1992–97 The eighth Five Year Plan provided an outlay of Rs 272,020 million (6.3%) for Indian Railways out of a total outlay of Rs 4,341,000 million for the full plan. Some of the main objectives of the eighth Plan were to generate adequate transport capacity, complete the process of rehabilitation of overaged assets, modernize the system to reduce cost and improve reliability, complete uni-gauge conversion of 6000 km of metre gauge (MG) and narrow gauge (NG) to broad gauge (BG), phase out steam locomotives, electrify 2700 route km, expand and upgrade intermodal operation, and improve manpower productivity.

1998 Konkan Railway system becomes fully operational on 26 January

1998 Guiness Certificate for Fairy Queen—the oldest working steam locomotive in the world

1999 Darjeeling Himalayan Railway declared World Heritage Site by UNESCO

1999 Centenary celebrations of the Nilgiri Mountain Railway

1999 Guiness certificate for Delhi main station equipped with the world's largest route relay interlocking system 2000 Railway Board consisted of seven members including a Chairman

1997–2002 The ninth Plan envisages an outlay of Rs 454,130 million, which is 14.1% of the total outlay of Rs 8,592,000 million for the full plan. Some of the main objectives were generation of adequate transport capacity for handling additional traffic, modernization and upgrading of the rail transport system, completion of the process of rehabilitation, replacement and renewal of overaged assets, and continuation of the policy of unit gauge.

2002 150th year of Indian Railways starts with effect from 16 April 2002

2002 Jan Shatabdi trains introduced

2002 East Cental Railway (HQ in Hazipur) and North Western Railway (HQ in Jaipur) become operational with effect from 1 October.

2003 Indian Railways has 16 (earlier 9) zones and 67 (earlier 59) divisions with effect from 1 April 2003

2003 Indian Railways completes 150 years of existence on 15 April 2003

2002–07 The Tenth Five Year Plan envisages an outlay of Rs 606,000 million, which is 4% of a total outlay of Rs 15,256,390 million for the full plan.

1.3 COMPARISION OF RAIL TRANSPORT WITH ROAD TRANSPORT:

Rail transport versus road transport

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.

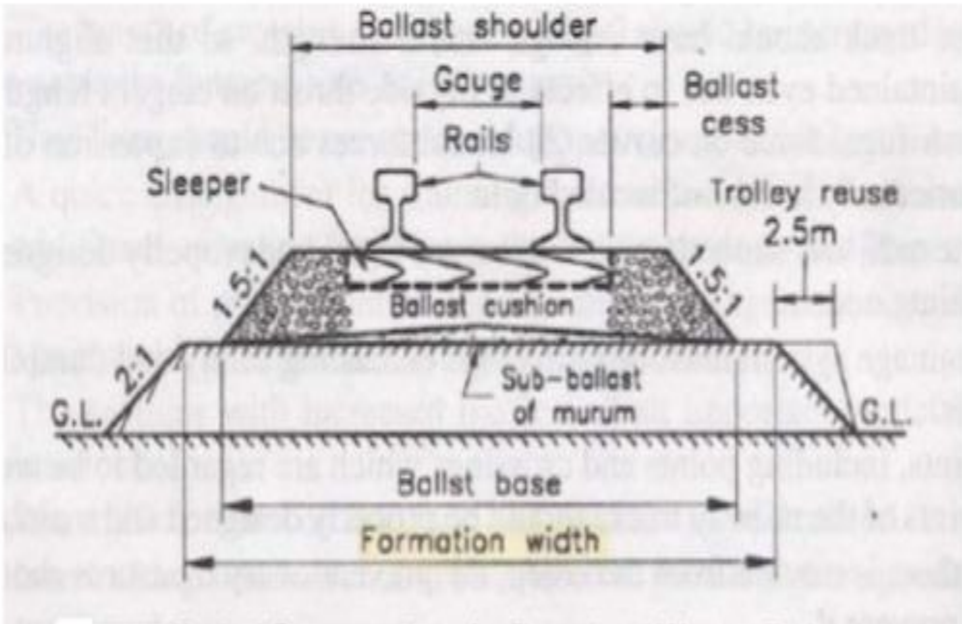
1.4 PERMANENT WAY AND ITS COMPONENTS:

The track on a railway or railroad, also known as the permanent way, is the structure consisting of the rails, fasteners, railroad ties (sleepers, British English) and ballast (or slab track), plus the underlying sub grade. • Railway Track is also known as Permanent Way.

Its Components:

a) RAILS
b) SLEEPERS
c) BALLAST
d) FIXTURES
e) FASTENERS

Track Cross-section

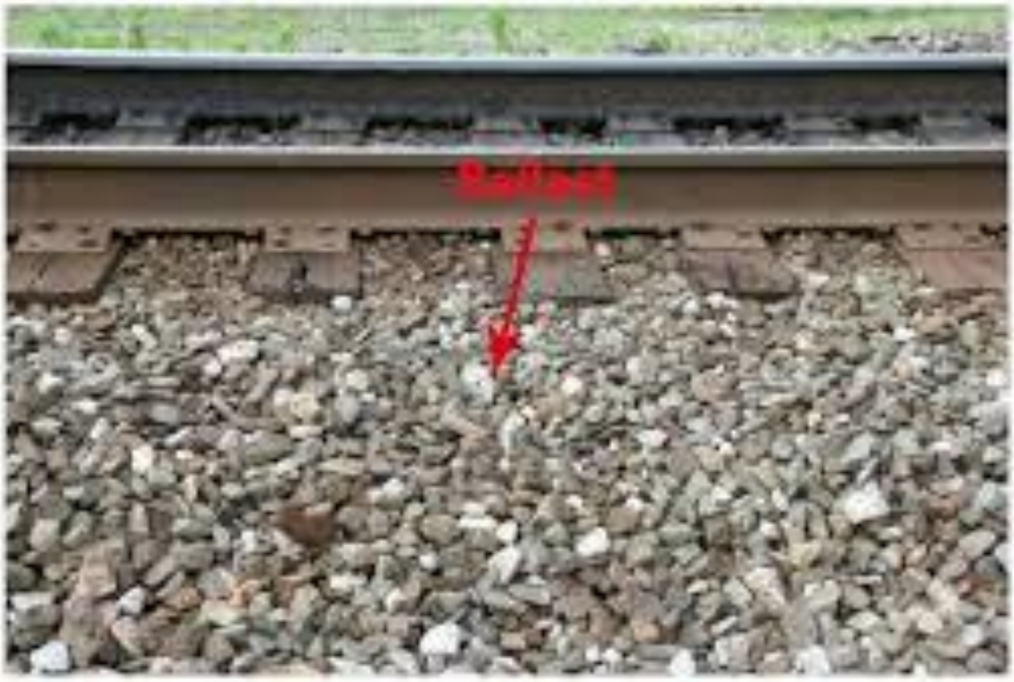


Typical Cross-section of a Permanent Way on Embankment.

1.4.1 RAILS: Rails are the members of the track laid in two parallel lines to provide an unchanging, continuous, and level surface for the movement of trains.

1.4.2 SLEEPERS: Sleepers are the transverse ties that are laid to support the rails. They have an important role in the track as they transmit the wheel load from the rails to the ballast. Several types of sleepers are in use on Indian Railways.

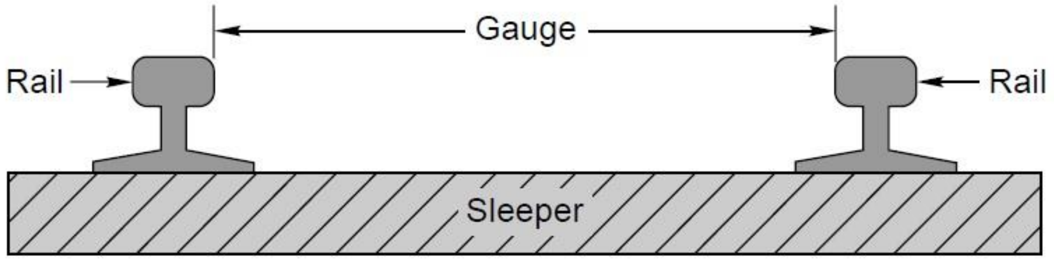
1.4.3 BALLAST: The ballast is a layer of broken stones, gravel, moorum, or any other granular material placed and packed below and around sleepers for distributing load from the sleepers to the formation. It provides drainage as well as longitudinal and lateral stability to the track.



1.4.4 FIXTURES AND FASTENERS: The purpose of providing fittings and fastenings in railway tracks is to hold the rails in their proper position in order to ensure the smooth running of trains. These fittings and fastenings are used for joining rails together as well as fixing them to the sleepers, and they serve their purpose so well that the level, alignment, and gauge of the railway track are maintained within permissible limits even during the passage of trains.

1.5 GAUGES IN INDIAN RAILWAYS:

Gauge is defined as the minimum distance between two rails. Indian Railways follows this standard practice and the gauge is measured as the clear minimum distance between the running faces of the two rails.



Gauge

1.5.1 Different Gauges on Indian Railways:

There are various types of Gauges in Indian Railways are:

a) BROAD GAUGE
b) METER GAUGE
c) NARROW GAUGE

Name of gauge	*Width (mm)*	*Width (feet)*	*Route kilometres*	*% of route kilometres*
Broad gauge (BG)	1676	5′6″	39,612	63.2
Metre gauge (MG)	1000	3′3.37″	19,210	30.7
Narrow gauge (NG)	762	2′6″	3838	6.1
	610	2′0″		
Total	–	–	62,660	100

BROAD GAUGE: Broad gauge is also called wide gauge or large line. The distance between the two tracks in these railway gauges is 1676 mm (5 ft 6 in). It would not be wrong to say that any gauge, wider than standard gauge or 1,435 mm (4 ft 8½ inches), is called broad gauge. The first railway line built in India was a Broad gauge line from Bore Bunder (now Chhatrapati Shivaji Terminus) to Thane in 1853. Broad gauge railway is also used on ports for crane etc. This gives better stability and they are even better than thinner gauges.

METER GAUGE: The distance between the two tracks is 1,000 mm (3 ft 3 3/8 in). The metre gauge lines were made to reduce the cost. All meter gauge lines except the Nilgiri Mountain Railway which is a legacy run on a meter gauge in India will be converted into broad gauge under project Unigauge.

NARROW GAUGE: The small gauge is called a Narrow gauge or a small line. The narrow-gauge railway is the railway track, in which distance between two tracks is 2 ft 6 in (762 mm) and 2 ft (610 mm). In 2015, there was a 1,500 km narrow gauge rail route, which is considered to be about 2% of the total Indian rail network. As the country is developing, small line services are expected to be completed by 2018. Now the small lines are being converted into big lines. Trains with small bogies now will no longer be able to see much. The Darjeeling Mountain Railway has declared UNESCO World Heritage on 24 July, 2008. Kalka Shimla Railway is also very popular.

1.6 IDEAL TRACKS IN INDIAN RAILWAYS:

The track or permanent way is the railroad on which trains run. It consists of two parallel rails fastened to sleepers with a specified distance between them. The sleepers are embedded in a layer of ballast of specified thickness spread over level ground known as *formation*. The ballast provides a uniform level surface and drainage, and transfers the load to a larger area of the formation. The rails are joined in series by fish plates and bolts and these are fastened to the sleepers with various types of fittings. The sleepers are spaced at a specified distance and are held in position by the ballast. Each component of the track has a specific function to perform. The rails act as girders to transmit the wheel load of trains to the sleepers.

The sleepers hold the rails in their proper positions, provide a correct gauge with the help of fittings and fastenings, and transfer the load to the ballast. The formation takes the total load of the track as well as of the trains moving on it.

In the early days, a temporary track used to be laid for carrying earth and other building material for the construction of a railway line; this temporary track used to be removed subsequently. The track is also called the permanent way in order to distinguish the final track constructed for the movement of trains from the temporary track constructed to carry building material.

The specifications adopted by Indian Railways for various types of railway tracks are discussed here. The stresses developed in the different components of a railway track due to moving wheel load are also elaborated.

REQUIREMENT OF GOOD TRACK:

A permanent way or track should provide a comfortable and safe ride at the maximum permissible speed with minimum maintenance cost. To achieve these objectives, a sound permanent way should have the following characteristics.

(a) The gauge should be correct and uniform.

(b) The rails should have perfect cross levels. In curves, the outer rail should have a proper superelevation to take into account the centrifugal force.

(c) The alignment should be straight and free of kinks. In the case of curves, a proper transition should be provided between the straight track and the curve.

(d) The gradient should be uniform and as gentle as possible. The change of gradient should be followed by a proper vertical curve to provide a smooth ride.

(e) The track should be resilient and elastic in order to absorb the shocks and vibrations of running trains.

(f) The track should have a good drainage system so that the stability of the track is not affected by waterlogging.

(g) The track should have good lateral strength so that it can maintain its stability despite variations in temperature and other such factors.

(h) There should be provisions for easy replacement and renewal of the various track components.

(i) The track should have such a structure that not only is its initial cost low, but also its maintenance cost is minimum.

Tilting of Rails:

Rails are tilted inward at an angle of 1 in 20 to reduce wear and tear on the rails as well as on the tread of the wheels. As the pressure of the wheel acts near the inner edge of the rail, there is heavy wear and tear of the rail. Lateral bending stresses are also created due to eccentric loading of rails. Uneven loading on the sleepers is also likely to cause them damage. To reduce wear and tear as well as lateral stresses, rails are titled at a slope of 1 in 20, which is also the slope of the wheel cone. The rail is tilted by ‘adzing’ the wooden sleeper or by providing canted bearing plates.

1.7 RAILS IN INDIAN RAILWAYS:

1.7.1 Introduction

Rails are the members of the track laid in two parallel lines to provide an unchanging, continuous, and level surface for the movement of trains. To be able to withstand stresses, they are made of high-carbon steel.

1.7.2 Function of Rails

Rails are similar to steel girders. These are provided to perform the following functions in a track.

(a) Rails provide a continuous and level surface for the movement of trains.

(b) Rails provide a pathway which is smooth and has very little friction. The friction between the steel wheel and the steel rail is about one-fifth of the friction between the pneumatic tyre and a metalled road.

(c) Rails serve as a lateral guide for the wheels.

(d) Rails bear the stresses developed due to vertical loads transmitted to them through axles and wheels of rolling stock as well as due to braking and thermal forces.

(e) Rails carry out the function of transmitting the load to a large area of the formation through sleepers and the ballast.

1.7.3 Types of Rails:

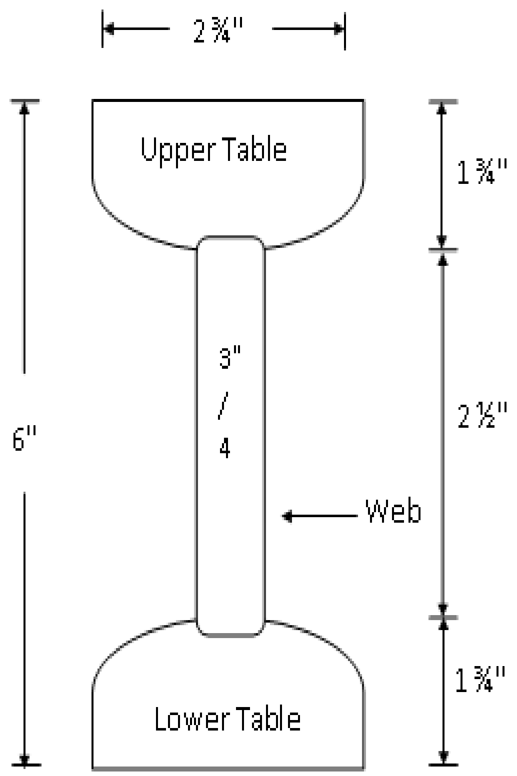
1. DOUBLE HEADED RAILS
2. BULL HEADED RAILS
3. FLAT FOOTED RAILS

1. Double Headed Rails

These rails indicate the early stage of development. It essentially consists of three parts,

- Upper Table
- Web
- Lower Table

Both the upper and lower tables were identical and they were introduced with the hope of double doubling the life of rails. When the upper table is worn out then the rails can be placed upside down reversed on the chair and so the lower table can be brought into use. But this idea soon turned out to b wrong because due to continuous contract of lower table with the chair made the surface of lower table rough and hence the smooth running of the train was impossible. Therefore, this type of rail is practically out of use. Nowadays, these rails vary in lengths from 20 – 24. A 100 lb double headed rail is shown in the figure.

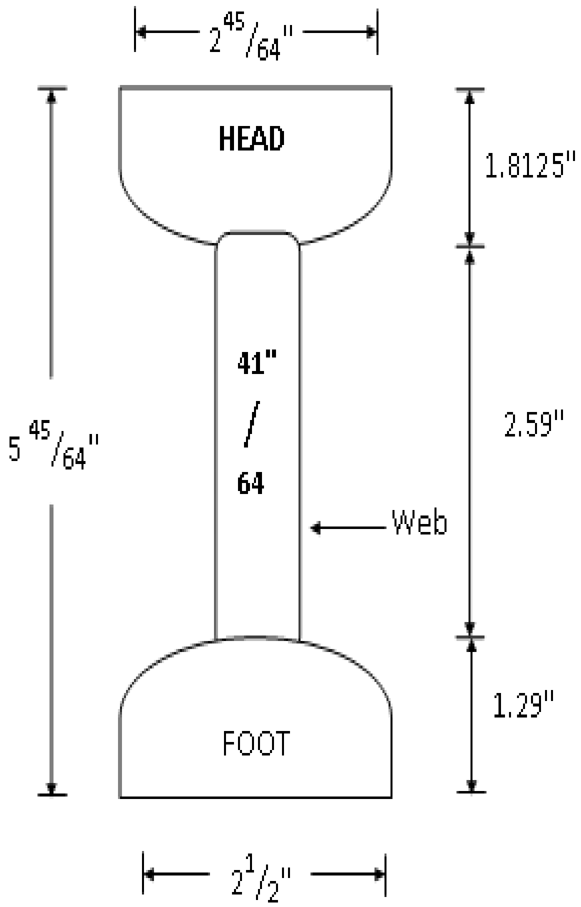


2. Bull Headed Rails

This type of rail also consists of three parts,

- The Head
- The Web
- The Foot

These rails were made of steel. The head is of larger size than foot and the foot is designed only to hold up properly the wooden keys with which rails are secured. Thus, the foot is designed only to furnish necessary strength and stiffness to rails. Two cast iron chairs are required per each sleeper when these rails are adopted. Their weight ranges from 85lb to 95lb and their length is up to 60 ft.

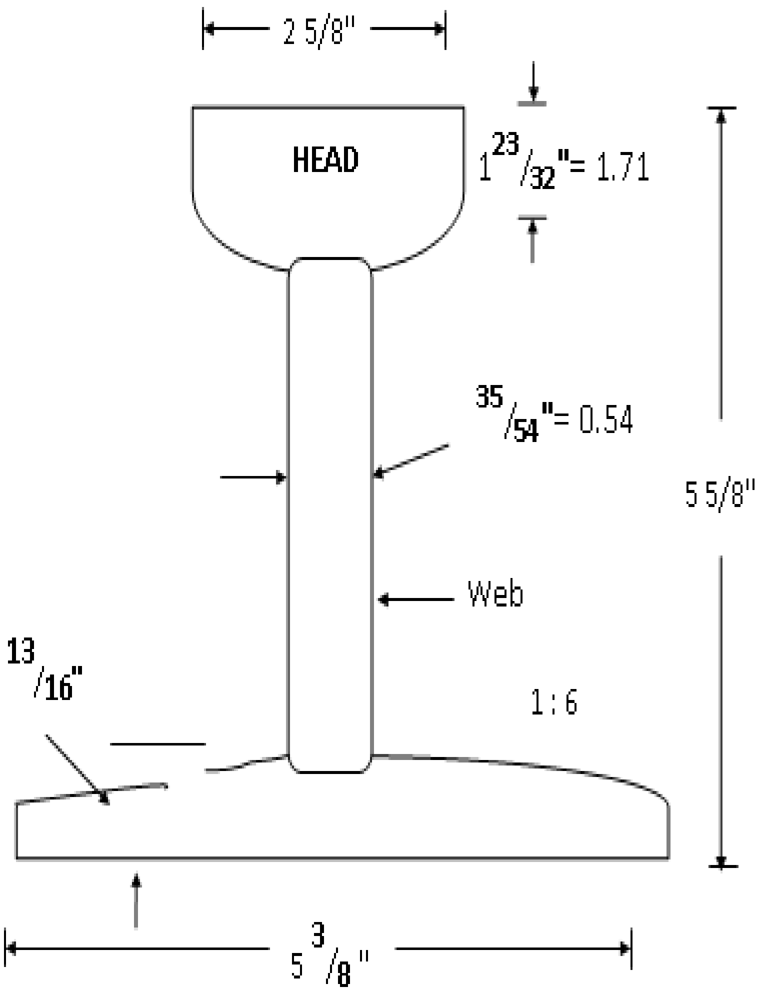


3. Flat Footed Rails

These rails were first of all invented by Charles Vignoles in 1836 and hence these rails are also called vignols rails. It consist of three parts

- The Head
- The Web
- The Foot

The foot is spread out to form a base. This form of rail has become so much popular that about 90% of railway tracks in the world are laid with this form of rails.



1.7.4 Requirements for an Ideal Rail Section:

The requirements for an ideal rail section are as follows.
(a) The rail should have the most economical section consistent with strength, stiffness, and durability.

(b) The centre of gravity of the rail section should preferably be very close to the mid-height of the rail so that the maximum tensile and compressive stresses are equal.

(c) A rail primarily consists of a head, a web, and a foot, and there should be an economical and balanced distribution of metal in its various components so that each of them can fulfil its requirements properly. The requirements, as well as the main considerations, for the design of these rail components are as follows.

Head: The head of the rail should have adequate depth to allow for vertical wear. The rail head should also be sufficiently wide so that not only is a wider running surface available, but also the rail has the desired lateral stiffness.

Web: The web should be sufficiently thick so as to withstand the stresses arising due to the loads bone by it, after allowing for normal corrosion.

Foot: The foot should be of sufficient thickness to be able to withstand vertical and horizontal forces after allowing for loss due to corrosion. The foot should be wide enough for stability against overturning. The design of the foot should be such that it can be economically and efficiently rolled.

Fishing angles: Fishing angles must ensure proper transmission of loads from the rails to the fish plates. The fishing angles should be such that the tightening of the plate does not produce any excessive stress on the web of the rail.

Height of the rail: The height of the rail should be adequate so that the rail has sufficient vertical stiffness and strength as a beam.

1.7.5 Length of rails

Theoretically, the longer the rail, the lesser the number of joints and fittings required and the lesser the cost of construction and maintenance. Longer rails are economical and provide smooth and comfortable rides. The length of a rail is, however, restricted due to the following factors.
(a)Lack of facilities for transport of longer rails, particularly on curves.

(b) Difficulties in manufacturing very long rails.

(c) Difficulties in acquiring bigger expansion joints for long rails.

(d) Heavy internal thermal stresses in long rails.

Taking the above factors into consideration, Indian Railways has standardized a rail length of 13 m (previously 42 ft) for broad gauge and 12 m (previously 39 ft) for MG and NG tracks. Indian Railways is also planning to use 26 m, and even longer, rails in its track system.

Rail Wear:

Due to the passage of moving loads and friction between the rail and the wheel, the rail head gets worn out in the course of service. The impact of moving loads, the effect of the forces of acceleration, deceleration, and braking of wheels, the abrasion due to rail–wheel interaction, the effects of weather conditions such as changes in temperature, snow, and rains, the presence of materials such as sand, the standard of maintenance of the track, and such allied factors cause considerable wear and tear of the vertical and lateral planes of the rail head. Lateral wear occurs more on curves because of the lateral thrust exerted on the outer rail by centrifugal force. A lot of the metal of the rail head gets worn out, causing the weight of the rail to decrease. This loss of weight of the rail section should not be such that the stresses exceed their permissible values. When such a stage is reached, rail renewal is called for.

In addition, the rail head should not wear to such an extent that there is the possibility of a worn flange of the wheel hiting the fish plate.

1.7.6 Type of Wear on Rails

A rail may face wear and tear in the following positions:

(a) on top of the rail head (*vertical wear*)

(b) on the sides of the rail head (*lateral wear*)

(c) on the ends of the rail (*battering of rail ends*)

Wear is more prominent at some special locations of the track. These locations are normally the following:

(a) on sharp curves, due to centrifugal forces

(b) on steep gradients, due to the extra force applied by the engine

(c) on approaches to railway stations, possibly due to acceleration and Deceleration

(d) in tunnels and coastal areas, due to humidity and weather effects

1.7.7 Methods to Reduce Wear

Based on field experience, some of the methods adopted to reduce vertical wear and lateral wear on straight paths and curves are indicated below.
(a) Better maintenance of the track to ensure good packing as well as proper alignment and use of the correct gauge

(b) Reduction in the number of joints by welding

(c) Use of heavier and higher UTS rails, which are more wear resistant

(d) Use of bearing plates and proper adzing in case of wooden sleepers

(e) Lubricating the gauge face of the outer rail in case of curves

(f) Providing check rails in the case of sharp curves

(g) Interchanging the inner and outer rails

(h) Changing the rail by carrying out track renewal

1.7.8 Rail Failure:

A rail is said to have failed if it is considered necessary to remove it immediately from the track on account of the defects noticed on it. The majority of rail failures originate from the fatigue cracks caused due to alternating stresses created in the rail section on account of the passage of loads. A rail section is normally designed to take a certain minimum GMT of traffic, but sometimes due to reasons such as an inherent defect in the metal, the section becomes weak at a particular point and leads to premature failure of the rail.

1.7.9 Causes of Rail Failures:

The main causes for the failure of rails are as follows.

Inherent defects in the rail Manufacturing defects in the rail, such as faulty chemical composition, harmful segregation, piping, seams, laps, and guide marks.

Defects due to fault of the rolling stock and abnormal traffic effects Flat spots in tyres, engine burns, skidding of wheels, severe braking, etc.

Excessive corrosion of rails Excessive corrosion in the rail generally takes place due to weather conditions, the presence of corrosive salts such as chlorides and constant exposure of the rails to moisture and humidity in locations near water columns, ashpits, tunnels, etc. Corrosion normally leads to the development of cracks in regions with a high concentration of stresses.

Badly maintained joints Poor maintenance of joints such as improper packing of joint sleepers and loose fittings.

Defects in welding of joints These defects arise either because of improper composition of the thermit weld metal or because of a defective welding technique.

Improper maintenance of track Ineffective or careless maintenance of the track or delayed renewal of the track.

Derailments Damages caused to the rails during derailment.

1.8 CONING OF WHEEL:

The tread of the wheels of a railway vehicle is not made flat, but sloped like a cone in order to enable the vehicle to move smoothly on curves as well as on straight tracks. The wheels are generally centrally aligned on a straight and level surface with uniform gauge, and the circumference of the treads of the inner and outer wheels are equal.

Coning of wheels causes wear and tear due to the slipping action. It is, however, useful as
(a) it helps the vehicle to negotiate a curve smoothly,

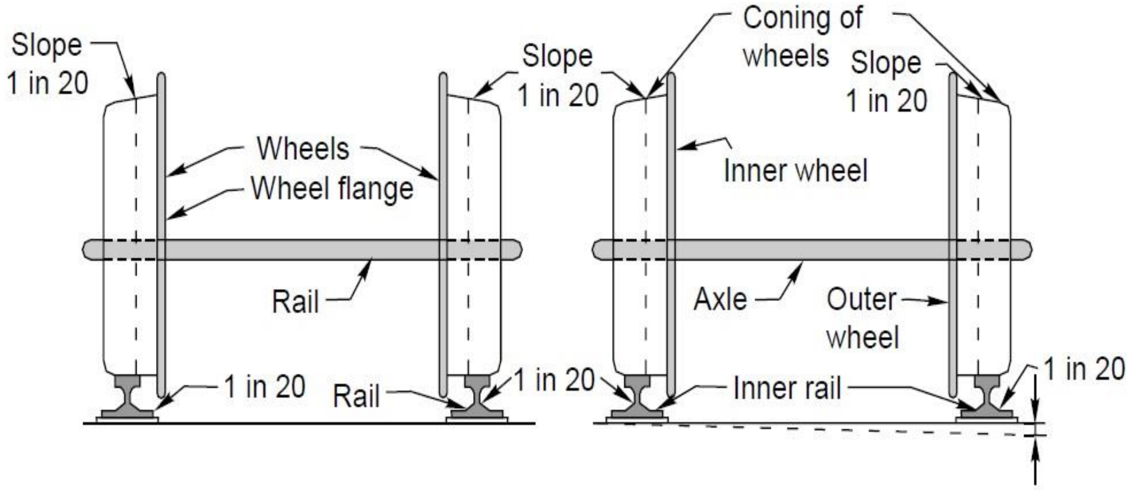
(b) it provides a smooth ride, and

(c) it reduces the wear and tear of the wheel flanges.

As far as the slip is concerned, it can be mathematically calculated as follows.

Slip = $2\pi\theta/360*G$

where θ is the angle at the centre of the curve fixed by the rigid wheel box and G is the gauge in metres.
The approximate value of the slip for broad gauge is 0.029 metre per degree of the curve.



Coning of wheels

1.8.1 ADVANTAGES OF CONING THE WHEELS:

•To reduce wear & tear of the wheel flanges and rails, which is due to rubbing action of flanges with inside face of the rail head

•To provide a possibility of lateral movement of the axle with its wheels

•To prevent the wheels from slipping to some extent

1.8.2 DISADVANATGES OF CONING:

•Smooth riding is produced by coning of wheels. But the pressure of the horizontal component near the inner edge of the rail has a tendency to wear the rail quickly

•The horizontal component tends to turn the rail outwardly and hence the gauge is widened sometimes

•If no base plate are provided, the sleepers under the outer edge of the rail are damaged

1.9 CREEP OF RAIL:

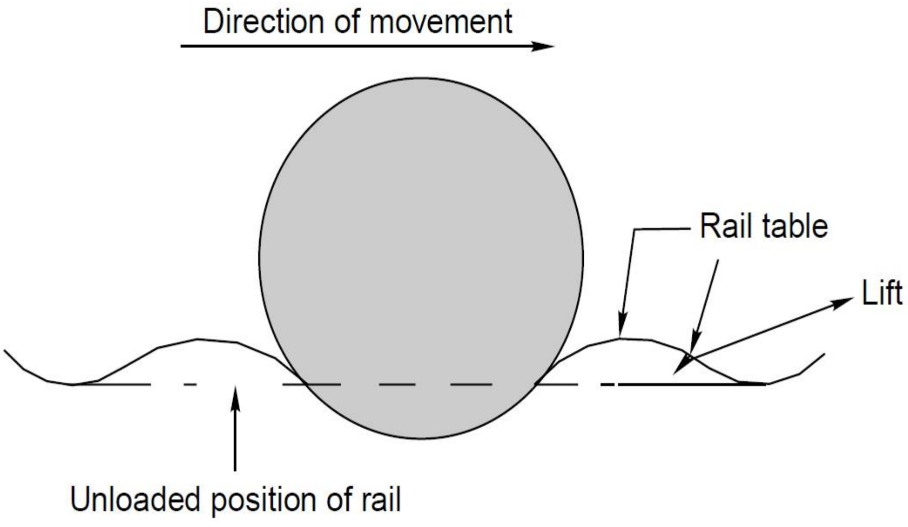
Creep is defined as the longitudinal movement of the rail with respect to the sleepers. Rails have a tendency to gradually move in the direction of dominant traffic. Creep is common to all railway tracks, but its magnitude varies considerably from place to place; the rail may move by several centimetres in a month at few places, while at other locations the movement may be almost negligible.

Theories for the Development of Creep

Various theories have been put forward to explain the phenomenon of creep and its causes, but none of them have proved to be satisfactory. The important theories are briefly discussed in the following subsections.

1.9.1 Wave Motion Theory

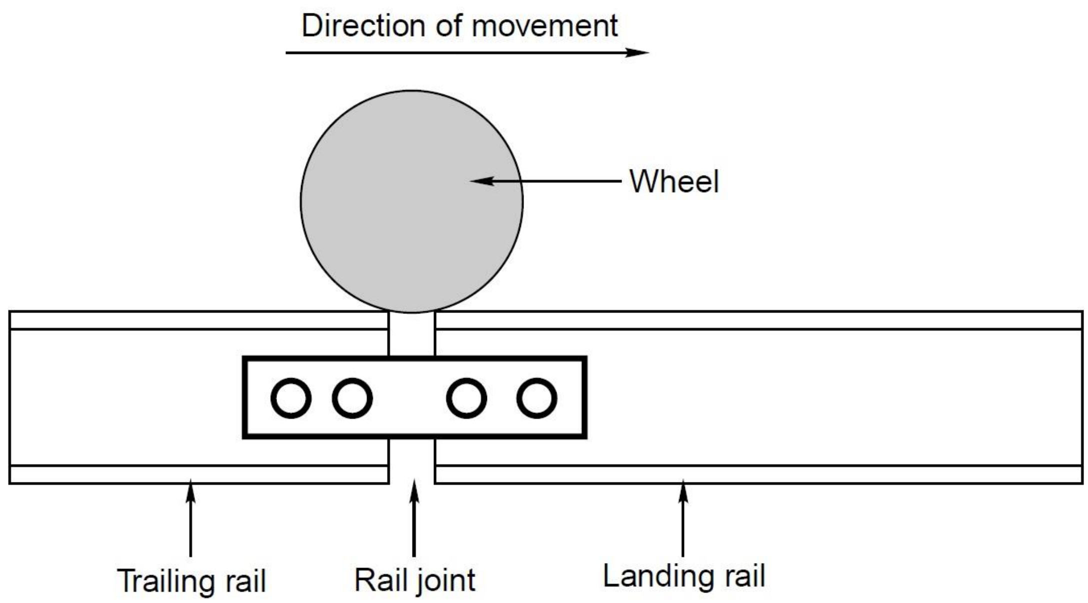
According to wave motion theory, wave motion is set up in the resilient track because of moving loads, causing a deflection in the rail under the load. The portion of the rail immediately under the wheel gets slightly depressed due to the wheel load. Therefore, the rails generally have a wavy formation. As the wheels of the train move forward, the depressions also move with them and the previously depressed portion springs back to the original level. This wave motion tends to move the rail forward with the train. The ironing effect of the moving wheels on the wave formed in the rail causes a longitudinal movement of the rail in the direction of traffic resulting in the creep of the rail.



Wave motion theory for development of creep

1.9.2 Percussion Theory

According to percussion theory, creep is developed due to the impact of wheels at the rail end ahead of a joint. As the wheels of the moving train leave the trailing rail at the joint, the rail gets pushed, forward causing it to move longitudinally in the direction of traffic, and that is how creep develops. Though the impact of a single wheel may be nominal, the continuous movement of several of wheels passing over thc joint pushes the facing or landing rail forward, thereby causing creep.



Percussion theory for development of creep

1.9.3 Causes of Creep

The main factors responsible for the development of creep are as follows.

Ironing effect of the wheel The ironing effect of moving wheels on the waves formed in the rail tends to cause the rail to move in the direction of traffic, resulting in creep.

Starting and stopping operations When a train starts or accelerates, the backward thrust of its wheels tends to push the rail backwards. Similarly, when the train slows down or comes to a halt, the effect of the applied brakes tends to push the rail forward. This in turn causes creep in one direction or the other.

Changes in temperature Creep can also develop due to variations in temperature resulting in the expansion and contraction of the rail. Creep occurs frequently during hot weather conditions.

Unbalanced traffic In a double-line section, trains move only in one direction, i.e., each track is unidirectional. Creep, therefore, develops in the direction of traffic.
In a single-line section, even though traffic moves in both directions, the volume of the traffic in each direction is normally variable. Creep, therefore, develops in the direction of predominant traffic.

Poor maintenance of track Some minor factors, mostly relating to the poor maintenance of the track, also contribute to the development of creep. These are as follows.
(a) Improper securing of rails to sleepers
(b) Limited quantities of ballast resulting in inadequate ballast resistance to the movement of sleepers
(c) Improper expansion gaps
(d) Badly maintained rail joints
(e) Rail seat wear in metal sleeper track
(f) Rails too light for the traffic carried on them
(g) Yielding formations that result in uneven cross levels
(h) Other miscellaneous factors such as lack of drainage, and loose packing, uneven spacing of sleepers.

1.9.4 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.

Other effects There are other miscellaneous effects of creep such as breaking of bolts and kinks in the alignment, which occur in various situations.

1.9.5 Measurement of Creep

Creep can be measured with the help of a device called creep indicator. It consists of two creep posts, which are generally rail pieces that are driven at 1-km intervals on either side of the track. For the purpose of easy measurement, their top level is generally at the same level as the rail. Using a chisel, a mark is made at the side of the bottom flange of the rail on either side of the track. A fishing string is then stretched between the two creep posts and the distance between the chisel mark and the string is taken as the amount of creep.

According to the prescribed stipulations, creep should be measured at intervals of about three months and noted in a prescribed register, which is to be maintained by the the permanent way inspector (PWI). Creep in excess of 150 mm (6 in.) should not be permitted on any track and not more than six consecutive rails should be found jammed in a single-rail track at one location. There should be no creep in approaches to points and crossings.

1.9.6 Adjustment of Creep

When creep is in excess of 150 mm resulting in maintenance problems, the same should be adjusted by pulling the rails back. This work is carried out after the required engineering signals have been put up and the necessary caution orders given. The various steps involved in the adjustment of creep are follows.

1. A careful survey of the expansion gaps and of the present position of rail joints is carried out.

2. The total creep that has been proposed to be adjusted and the correct expansion gap that is to be kept are decided in advance.

3. The fish plates at one end are loosened and those at the other end are removed. Sleeper fittings, i.e., spikes or keys, are also loosened or removed.

4. The rails are then pulled back one by one with the help of a rope attached to

a hook. The pulling back should be regulated in such a way that the rail joints remain central and suspended on the joint sleepers.

5. The pulling back of rails is a slow process since only one rail is dealt with at a time and can be done only for short isolated lengths of a track. Normally, about 40–50 men are required per kilometre for adjusting creep.

6. When creep is required to be adjusted for longer lengths, five rail lengths are tackled at a time. The procedure is almost the same as the preceding steps except that instead of pulling the rails with a rope, a blow is given to them using a cut rail piece of a length of about 5 m.

1.9.7 Measures to Reduce Creep

To reduce creep in a track, it should be ensured that the rails are held firmly to the sleepers and that adequate ballast resistance is available. All spikes, screws, and keys should be driven home. The toe load of fastenings should always be slightly more than the ballast resistance. Creep anchors can effectively reduce the creep in a track. At least eight of these must be provided per panel. Out of the large number of creep anchors tried on Indian Railways, the 'fair T' and 'fair V' anchors, have been standardized for use. The fair 'V' anchor, which is more popular. The creep anchor should fit snugly against the sleeper for it to be fully effective. The following measures are also helpful in reducing creep.

(a) The track should be well maintained—sleepers should be properly packed and the crib and shoulder ballast should be well compacted.

(b) A careful lookout should be kept for jammed joints that exist in series. In the case of a fish-plated track, more than six consecutive continuously jammed joints should not be permitted. In the case of SWR tracks, more than two consecutive jammed joints should not be permitted at rail temperatures lower than the maximum daily temperature (tm) in the case of zones I and II and lower than (tm – 5°C) in the case of zones III and IV. Regular adjustment may be necessitated on girder bridges.

(c) Anti creep bearing plates should be provided on wooden sleepers to arrest creep, but joints sleepers should have standard canted bearing plates with rail screws.

1.10 SLEEPERS IN INDIAN RAILWAYS:

Sleepers are the transverse ties that are laid to support the rails. They have an important role in the track as they transmit the wheel load from the rails to the ballast. Several types of sleepers are in use on Indian Railways.

1.10.1 Functions and Requirements of Sleepers:

The main **functions** of sleepers are as follows.
(a) Holding the rails in their correct gauge and alignment

(b) Giving a firm and even support to the rails

(c) Transferring the load evenly from the rails to a wider area of the ballast

(d) Acting as an elastic medium between the rails and the ballast to absorb the blows and vibrations caused by moving loads

(e) Providing longitudinal and lateral stability to the permanent way

(f) Providing the means to rectify the track geometry during their service life.

Apart from performing these functions the ideal sleeper should normally fulfil the following **requirements.**

(a) The initial as well as maintenance cost should be minimum.

(b) The weight of the sleeper should be moderate so that it is convenient to handle.

(c) The designs of the sleeper and the fastenings should be such that it is possible to fix and remove the rails easily.

(d) The sleeper should have sufficient bearing area so that the ballast under it is not crushed.

(e) The sleeper should be such that it is possible to maintain and adjust the gauge properly.

(f) The material of the sleeper and its design should be such that it does not break or get damaged during packing.

(g) The design of the sleeper should be such that it is possible to have track circuiting.

The design of the sleeper should be such that it is possible to have track circuiting.

(h) The sleeper should be capable of resisting vibrations and shocks caused by the passage of fast moving trains.

(i) The sleeper should have anti-sabotage and anti-theft features.

1.10.2 Types of Sleepers

The sleepers mostly used on Indian Railways are (i) wooden sleepers, (ii) cast iron (CI) sleepers, (ii) steel sleepers, and (iv) concrete sleepers.

Wooden Sleepers

The wooden sleeper is the most ideal type of sleeper, and its utility has not decreased with the passage of time.

Advantages

(a) Cheap and easy to manufacture
(b) Absorbs shocks and bears a good capacity to dampen vibrations; therefore, retains the packing well
(c) Easy handling without damage
(d) Suitable for track-circuited sections
(e) Suitable for areas with yielding formations
(f) Alignment can be easily corrected
(g) More suitable for modern methods of maintenance
(h) Can be used with or without stone ballast
(i) Can be used on bridges and ashpits also
(j) Can be used for gauntleted track

Disadvantages

(a) Lesser life due to wear, decay, and attack by vermin
(b) Liable to mechanical wear due to beater packing
(c) Difficult to maintain the gauge
(d) Susceptible to fire hazards
(e) Negligible scrap value

Steel Trough Sleeper

About 27% of the track on Indian Railways is laid on steel sleepers. The increasing shortage of timber in the country and other economical factors are mainly responsible for the use of steel sleepers in India. Steel sleepers have the following main advantages/disadvantages over wooden sleepers.

Advantages

(a) Long life
(b) Easy to maintain gauge and less maintenance problems
(c) Good lateral rigidity
(d) Less damage during handling and transport
(e) Simple manufacturing process
(f) Very good scrap value
(g) Free from decay and attack by vermin
(h) Not susceptible to fire hazards

Disadvantages

(a) Liable to corrode
(b) Unsuitable for track-circuited areas

Cast Iron Sleepers

Cast iron sleepers are being extensively used on Indian Railways and about 45% of the track at present consists of CI sleepers, which may be either pot type or plate
type. The main advantages and disadvantages of CI sleepers over steel trough sleepers are the following.

Advantages

(a) Less corrosion
(b) Less probability of cracking at rail seat
(c) Easy to manufacture
(d) Higher scrap value

Disadvantages

(a) Gauge maintenance is difficult as tie bars get bent
(b) Provides less lateral stability
(c) Unsuitable for track-circuited lines
(d) Not very suitable for mechanical maintenance and/or MSP because of rounded bottom
(e) Susceptible to breakage

Concrete Sleepers

The need for concrete sleepers has been felt mainly due to economic considerations coupled with changing traffic patterns. In the early days of Indian Railways, wood was the only material used for making sleepers in Europe. Even in those days, the occasional shortage of wooden sleepers and their increasing price posed certain problems and this gave a fillip to the quest for an alternative material for sleepers.

With the development of concrete technology in the nineteenth century, cement concrete had established its place as a versatile building material and could be adopted suitably to meet the requirements of a railway sleeper.

Advantages and disadvantages:

Concrete sleepers have the following advantages and disadvantages.

Advantages

(a) Concrete sleepers, being heavy, lend more strength and stability to the track and are specially suited to LWR due to their great resistance to buckling of the track.

(b) Concrete sleepers with elastic fastenings allow a track to maintain better gauge, cross level, and alignment. They also retain packing very well.

(c) Concrete sleepers, because of their flat bottom, are best suited for modern methods of track maintenance such as MSP and mechanical maintenance, which have their own advantages.

(d) Concrete sleepers can be used in track-circuited areas, as they are poor conductors of electricity.

(e) Concrete sleepers are neither inflammable nor subjected to damage by pests or corrosion under normal circumstances.

(f) Concrete sleepers have a very long lifespan, probably 40–50 years. As such rail and sleeper renewals can be matched, which is a major economic advantage.

(g) Concrete sleepers can generally be mass produced using local resources.

Disadvantages

(a) Handling and laying concrete sleepers is difficult due to their large weights. Mechanical methods, which involve considerable initial expenditure, have to be adopted for handling them.

(b) Concrete sleepers are heavily damaged at the time of derailment.

(c) Concrete sleepers have no scrap value.

(d) Concrete sleepers are not suitable for beater packing.

(f) Concrete sleepers should preferably be maintained by heavy ‘on track’ tampers.

1.10.3 Sleeper Density and Spacing of Sleepers

Sleeper density is the number of sleepers per rail length. It is specified as $M + x$ or $N + x$, where M or N is the length of the rail in metres and x is a number that varies according to factors such as (a) axle load and speed, (b) type and section of rails, (c) type and strength of the sleepers, (d) type of ballast and ballast cushion, and (e) nature of formation.

If the sleeper density is $M + 7$ on a broad gauge route and the length of the rail is 13 m, it means that 13 + 7 = 20 sleepers will be used per rail on that route. The number of sleepers in a track can also be specified by indicating the number of sleepers per kilometre of the track. For example, 1540 sleepers/km. This specification becomes more relevant particularly in cases where rails are welded and the length of the rail does not have much bearing on the number of sleepers required.

This system of specifying the number of sleepers per kilometre exists in many foreign countries and is now being adopted by Indian Railways as well.
The spacing of sleepers is fixed depending upon the sleeper density. Spacing is not kept uniform throughout the rail length. It is closer near the joints because of the weakness of the joints and impact of moving loads on them. There is, however, a limitation to the close spacing of the sleepers, as enough space is required for working the beaters that are used to pack the joint sleepers.

1.11 BALLAST IN INDIAN RAILWAYS:

The ballast is a layer of broken stones, gravel, moorum, or any other granular material placed and packed below and around sleepers for distributing load from the sleepers to the formation. It provides drainage as well as longitudinal and lateral stability to the track.

1.11.1 Functions of Ballast

The ballast serves the following functions in a railway track.

- Provides a level and hard bed for the sleepers to rest on.
- Holds the sleepers in position during the passage of trains.
- Transfers and distributes load from the sleepers to a large area of the formation.
- Provides elasticity and resilience to the track for proper riding comfort.
- Provides the necessary resistance to the track for longitudinal and lateral stability.
- Provides effective drainage to the track.
- Provides an effective means of maintaining the level and alignment of the track.

1.11.2 Requirements of a Good Ballast

Ballast material should possess the following properties.

(a) It should be tough and wear resistant.

(b) It should be hard so that it does not get crushed under the moving loads.

(c) It should be generally cubical with sharp edges.

(d) It should be non-porous and should not absorb water.

(e) It should resist both attrition and abrasion.

(f) It should be durable and should not get pulverized or disintegrated under adverse weather conditions.

(g) It should allow for good drainage of water.

(h) It should be cheap and economical.

1.12 FIXTURES AND FASTENERS:

The purpose of providing fittings and fastenings in railway tracks is to hold the rails in their proper position in order to ensure the smooth running of trains. These fittings and fastenings are used for joining rails together as well as fixing them to the sleepers, and they serve their purpose so well that the level, alignment, and gauge of the railway track are maintained within permissible limits even during the passage of trains.

1.12.1 Fish Plates

The name ‘fish plate’ derives from the fish-shaped section of this fitting.
The function of a fish plate is to hold two rails together in both the horizontal and vertical planes. Fish plates are manufactured using a special type of steel (Indian Railways specification T-1/57) with composition given below:

Carbon: 0.30–0.42%

Manganese: not more than 0.6%

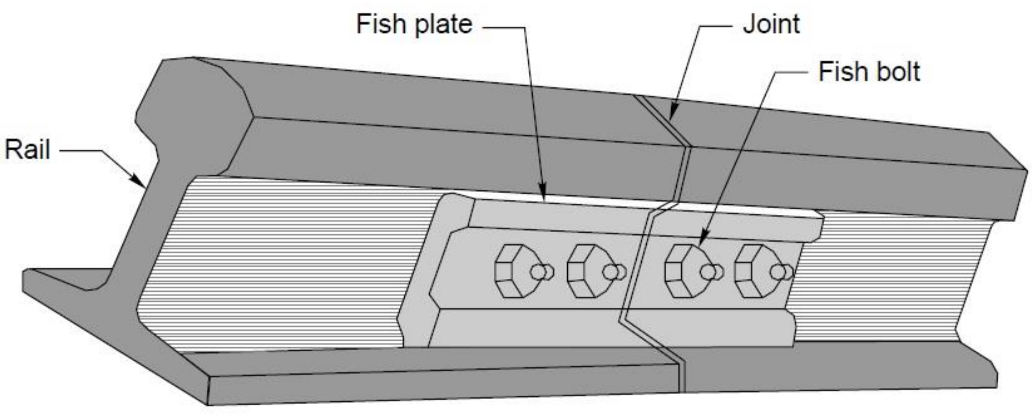
Silicon: not more than 0.15%

Sulphur and phosphorous: not more than 0.06%

The steel used for fish plates should have a minimum tensile strength of 5.58 to 6.51 t/cm2 with a minimum elongation of 20%. Fish plates are designed to have roughly the same strength as the rail section, and as such the section area of two fish plates connecting the rail ends is kept about the same as that of the rail section.

As fish plates do not go as deep as the rail, the strength of a pair of fish plates is less than that of the rail section, about 55%, when only vertical bending is taken into consideration.

Fish plates are so designed that the fishing angles at the top and bottom surface coincide with those of the rail section so as to allow perfect contact with the rail



Fish plate

1.12.2 Fish Boltes

Fish bolt is used for connecting the rail ends with the help of rail joints. Each rail joint needs at least two fish bolts according to the rail standard, and the bolt should be in proper size and suitable place. Rail bolt is usually used with spring washer and nut to fasten the rail tightly. The size of rail bolts varies as the variation of the rails or fish plate. Fish bolts can be classified into many types such as BHON fish Bolt, Cup Head Oval Neck Fish Bolt, Heavy Hex Head Frog Bolts, Anchor Bolt, Tunnel Bolt, etc. AGICO provide various types of rail bolt suited for different standard rails such as BS, ASTM and Din, etc.

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

SUBJECT: TRANSPORT ENGINEERING 2 **SUBJECT CODE: CE-310B**

COURSE- BTECH **BRANCH: CIVIL ENGINEERING**

SEMESTER 6TH **CHAPTER NAME: RAILWAYS UNIT 2**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

2.1 TURNOUT:

Points and crossings are provided to help transfer railway vehicles from one track to another. The tracks may be parallel to, diverging from, or converging with each other. Points and crossings are necessary because the wheels of railway vehicles are provided with inside flanges and, therefore, they require this special arrangement in order 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*.

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

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.

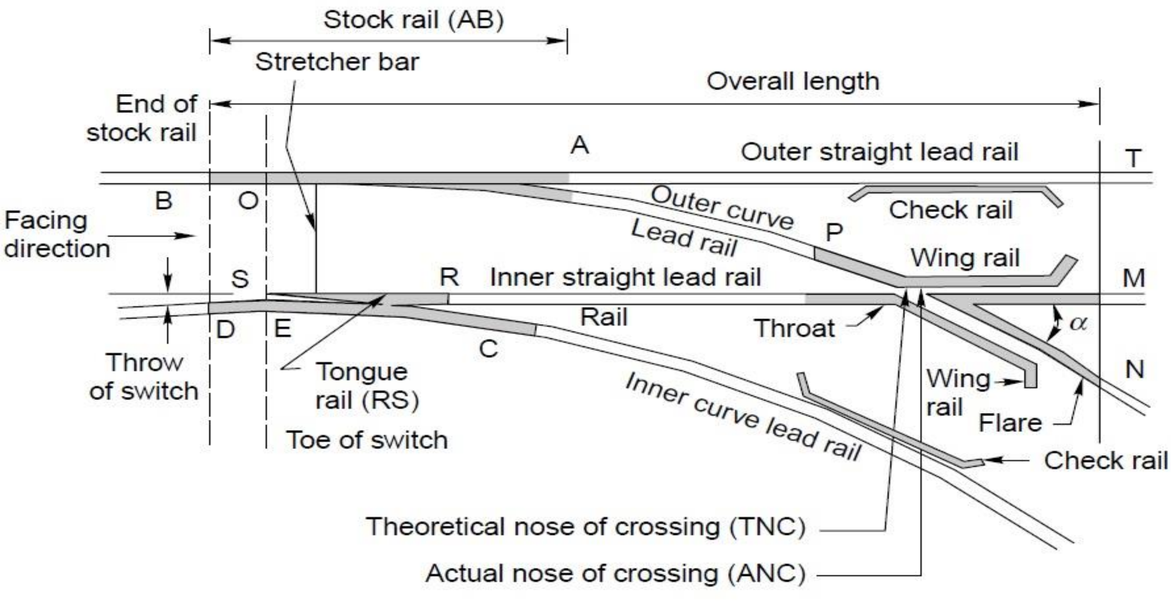
Radius of turnout (R) This is the radius of the turnout. It may be clarified that the radius of the turnout is equal to the radius of the centre line of the turnout ($R1$) plus half the gauge width.

$R = R1 + 0.5G$

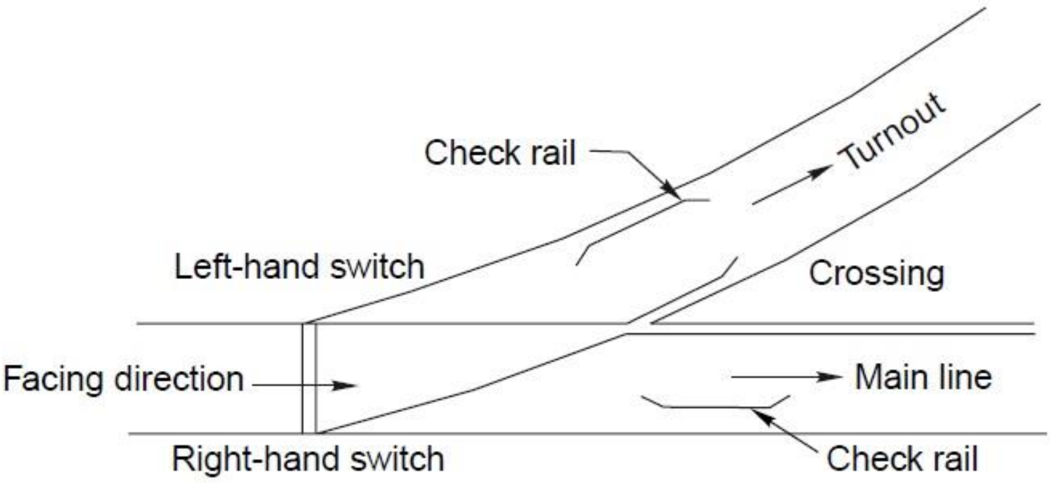
As the radius of a curve is quite large, for practical purposes, R may be taken to be equal to $R1$.

2.1.1 Direction of a turnout:

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



Constituents of a turnout



Left-hand 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

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

2.1.2 Switches

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

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

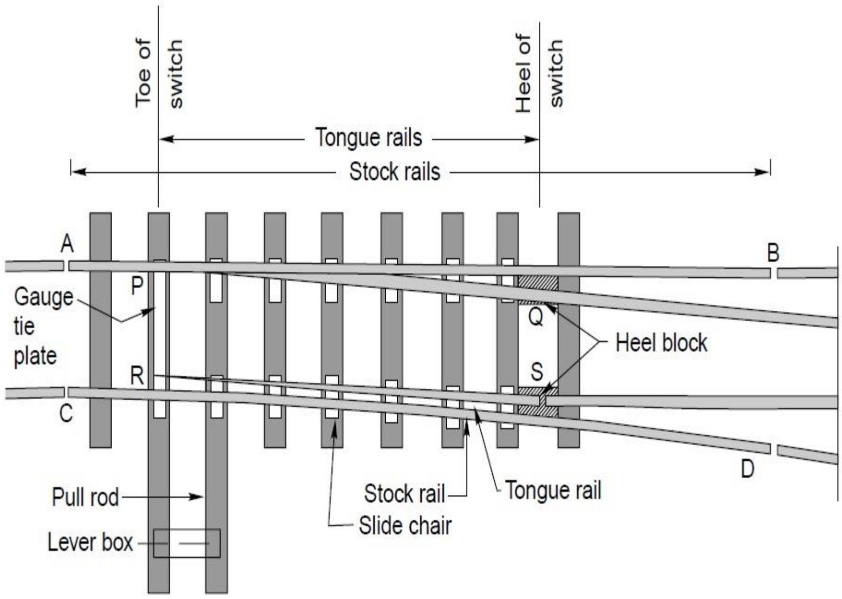
(b) A pair of tongue rails, PQ and RS, also known as switch rails, made of medium-manganese steel to withstand wear. The tongue rails are machined to a very thin section to obtain a snug fit with the stock rail. The tapered end of the tongue rail is called the *toe* and the thicker end is called the *heel*.

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

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

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

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



Details of a switch

2.1.3 Types of Switches

Switches are of two types, namely, *stud switch* and *split switch*. In a stud type of switch, no separate tongue rail is provided and some portion of the track is moved from one side to the other side. Stud switches are no more in use on Indian Railways.

They have been replaced by split switches. These consist of a pair of stock rails and a pair of tongue rails. Split switches may again be of two types—loose heel type and fixed heel type.

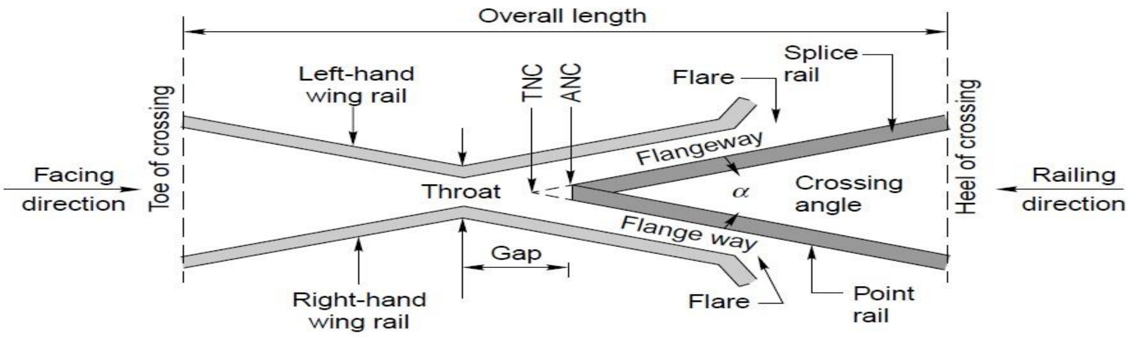
2.2 CROSSING:

A crossing or *frog* is a device introduced at the point where two gauge faces cross each other to permit the flanges of a railway vehicle to pass from one track to another. To achieve this objective, a gap is provided from the throw to the nose of the crossing, over which the flanged wheel glides or jumps. In order to ensure that this flanged wheel negotiates the gap properly and does not strike the nose, the other wheel is guided with the help of check rails. A crossing consists of the following components, shown in Fig.

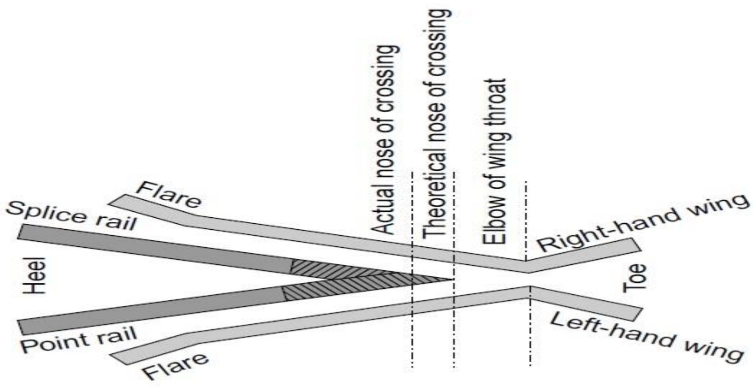
(a) Two rails, the *point rail* and *splice rail*, which are machined to form a nose. The point rail ends at the nose, whereas the splice rail joins it a little behind the nose. Theoretically, the points rail should end in a point and be made as thin as possible, but such a knife edge of the point rail would break off under the movement of traffic. The point rail, therefore, has its fine end slightly cut off to form a blunt nose, with a thickness of 6 mm (1/4"). The toe of the blunt nose is called the *actual nose of crossing* (ANC) and the theoretical point where gauge faces from both sides intersect is called the *theoretical nose of crossing* (TNC). The 'V' rail is planed to a depth of 6 mm (1/4") at the nose and runs out in 89 mm to stop a wheel running in the facing direction from hitting the nose.

(b) 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.

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



Details of a crossing



Point rail and splice rail

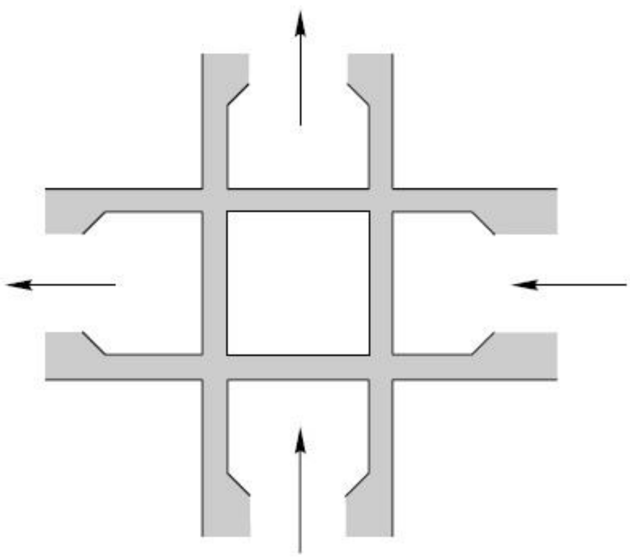
2.2.1 Types of Crossings

A crossing may be of the following types.

(a) An *acute angle crossing* or ‘V’ crossing in which the intersection of the two gauge faces forms an acute angle. For example, when a right rail crosses a left rail, it makes an acute crossing. Thus, unlike rail crossings form an acute crossing.

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

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



Square crossing

2.2.2 CMS Crossing

Due to increase in traffic and the use of heavier axle loads, the ordinary built-up crossings manufactured from medium-manganese rails are subjected to very heavy wear and tear, specially in fast lines and suburban sections with electric traction. Past experience has shown that the life of such crossings varies from 6 months to 2 years, depending on their location and the service conditions. CMS crossings possess higher strength, offer more resistance to wear, and consequently have a longer life. The following are the main advantages of CMS crossings.

(a) Less wear and tear.

(b) Longer life: The average life of a CMS crossing is about four times more than that of an ordinary built-up crossing.

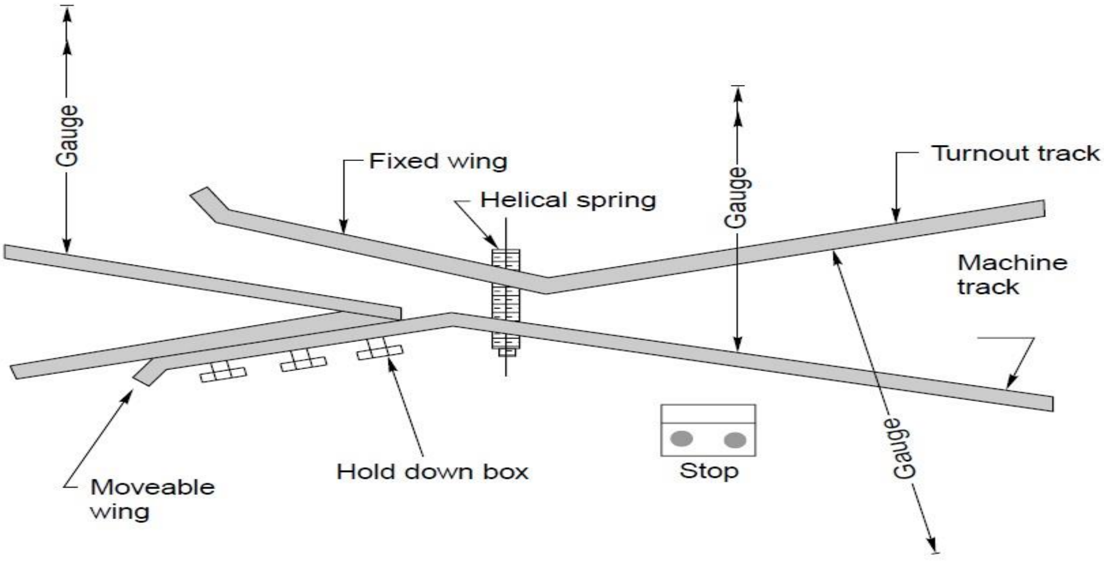
(c) CMS crossings are free from bolts as well as other components that normally tend to get loose as a result of the movement of traffic.

These days CMS crossings are preferred on Indian Railways. Though their initial cost is high, their maintenance cost is relatively less and they last longer. However, special care must be taken in their laying and maintenance. Keeping this in view, CMS crossings have been standardized on Indian Railways. On account of the limited availability of CMS crossings in the country, their use has, however, been restricted for the time being to group A routes and those lines of other routes on which traffic density is over 20 GMT. These should also be reserved for use on heavily worked lines of all the groups in busy yards.

2.2.3 Spring or Movable Crossing

In a spring crossing, one wing rail is movable and is held against the V of the crossing with a strong helical spring while the other wing rail is fixed.

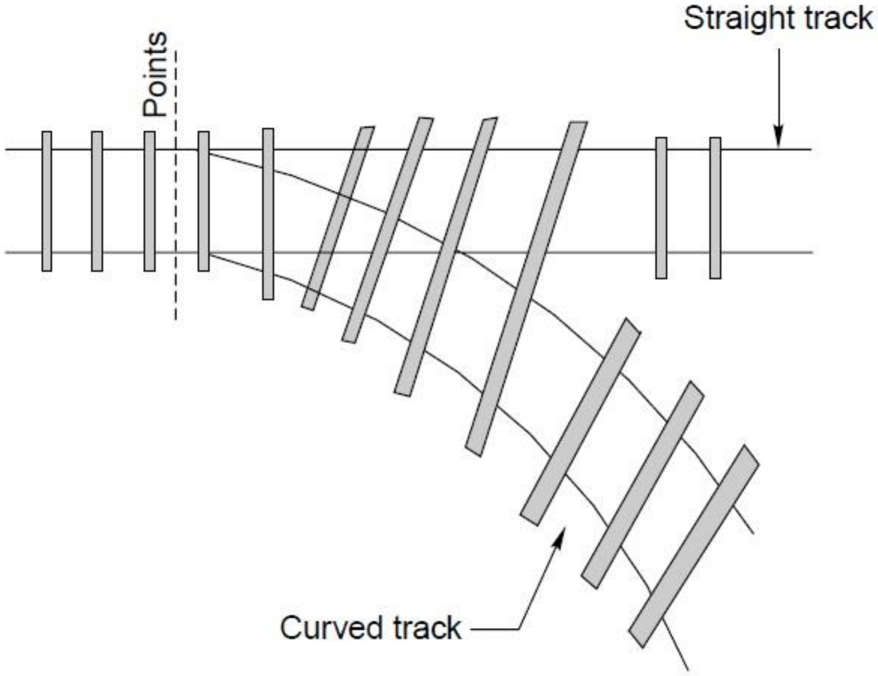
When a vehicle passes on the main track, the movable wing rail is snug with the crossing and the vehicle does not need to negotiate any gap at the crossing. In case the vehicle has to pass over a turnout track, the movable wing is forced out by the wheel flanges and the vehicle has to negotiate a gap as in a normal turnout. This type of crossing is useful when there is high-speed traffic on the main track and slow-speed traffic on the turnout track.



Spring or movable crossing

2.2.4 Position of Sleepers at Points and Crossings

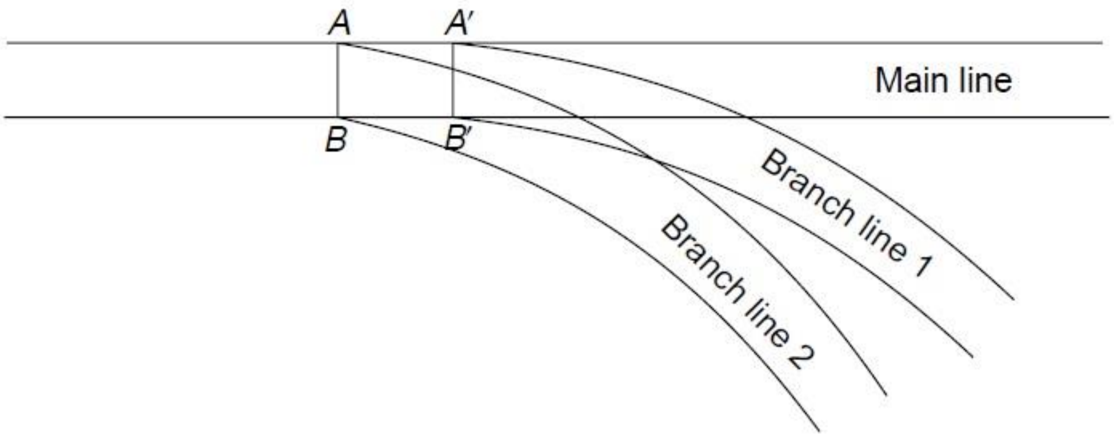
Sleepers are normally perpendicular to the track. At points and crossings, a situation arises where the sleepers have to cater to the main line as well as to the turnout portion of the track. For this purpose, longer sleepers are used for some length of the track.



Sleepers for points and crossings

2.2.5 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 turnout with similar flexure

2.2.6 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 consisting of two tracks of the same gauge crossing each other.

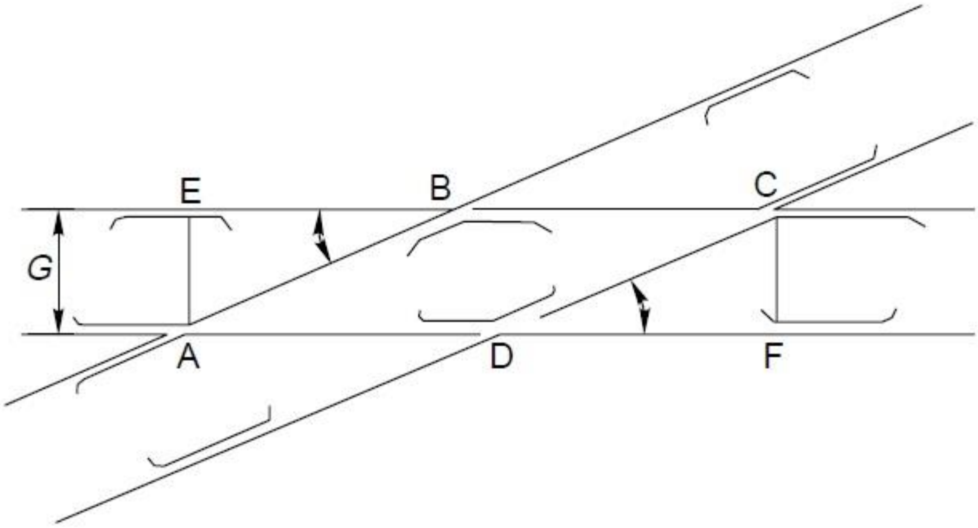
In the layout, ABCD is a rhombus with four equal sides. The length of the various constituents may be calculated as follows.

$EB = DF = AE \cot\alpha = GN$

$AB = BC = G \operatorname{cosec}\alpha$

Diagonal $AC = G \operatorname{cosec}\alpha/2$

Diagonal $BD = G \sec\alpha/2$



Diamond crossing

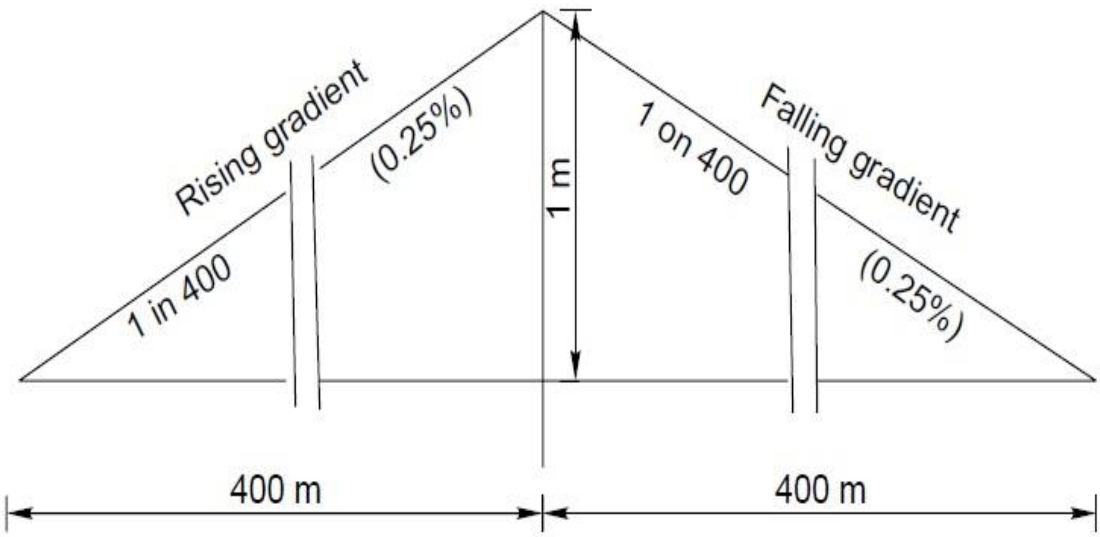
It can be seen from the layout that the length of the gap at points B and D increases as the angle of crossing decreases. Longer gaps increase the chances of the wheels, particularly of a small diameter, being deflected to the wrong side of the nose. On Indian Railways, the flattest diamond crossing 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.

2.3 Gradients:

Gradients are provided to negotiate the rise or fall in the level of the railway track. A rising gradient is one in which the track rises in the direction of the movement of traffic and a down or falling gradient is one in which the track loses elevation in the direction of the movement of traffic.

A gradient is normally represented by the distance travelled for a rise or fall of one unit. Sometimes the gradient is indicated as per cent rise or fall. For example, if there is a rise of 1 m in 400 m, the gradient is 1 in 400 or 0.25%,
Gradients are provided to meet the following objectives.
(a) To reach various stations at different elevations
(b) To follow the natural contours of the ground to the extent possible
(c) To reduce the cost of earthwork.

The following types of gradients are used on the railways.
(a) Ruling gradient
(b) Pusher or helper gradient
(c) Momentum gradient
(d) Gradients in station yards



Rising and falling gradient

2.3.1 Ruling Gradient

The ruling gradient is the steepest gradient that exists in a section. It determines the maximum load that can be hauled by a locomotive on that section. While deciding the ruling gradient of a section, it is not only the severity of the gradient but also its length as well as its position with respect to the gradients on both sides that have to be taken into consideration.

The power of the locomotive to be put into service on the track also plays an important role in taking this decision, as the locomotive should have adequate power to haul the entire load over the ruling gradient at the maximum permissible speed.

2.3.2 Pusher or Helper Gradient

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

2.3.3 Momentum Gradient

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

2.3.4 Gradients in Station Yards

The gradients in station yards are quite flat due to the following reasons.

(a) To prevent standing vehicles from rolling and moving away from the yard due to the combined effect of gravity and strong winds.

(b) To reduce the additional resistive forces required to start a locomotive to the extent possible.

It may be mentioned here that generally, yards are not levelled completely and certain flat gradients are provided in order to ensure good drainage. The maximum gradient prescribed in station yards on Indian Railways is 1 in 400, while the recommended gradient is 1 in 1000.

2.3.5 Radius or degree of a curve:

A curve is defined either by its radius or by its degree. The degree of a curve (*D*) is the angle subtended at its centre by a 30.5-m or 100-ft chord.
The value of the degree of the curve can be determined as indicated below.
Circumference of a circle = $2\pi R$
Angle subtended at the centre by a circle with this circumference = 360°
Angle subtended at the centre by a 30.5-m chord, or degree of curve= $1750/R$ (approx., R is in metres)
In cases where the radius is very large, the arc of a circle is almost equal to the chord connecting the two ends of the arc. The degree of the curve is thus given by the following formulae
$D = 1750/R$ (when R is in metres)
$D = 5730/R$ (when R is in feet)
A 2° curve, therefore, has a radius of 1750/2 = 875 m.

2.3.6 Superelevation

The following terms are frequently used in the design of horizontal curves.

Superelevation or cant

Superelevation or cant (*C*a) is the difference in height between the outer and the inner rail on a curve. It is provided by gradually lifting the outer rail above the level of the inner rail. The inner rail is taken as the reference rail and is normally maintained at its original level. The inner rail is also known as the *gradient rail*. The main functions of superelevation are the following.

(a) To ensure a better distribution of load on both rails
(b) To reduce the wear and tear of the rails and rolling stock
(c) To neutralize the effect of lateral forces
(d) To provide comfort to passengers

2.3.7 Equilibrium speed

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

Maximum permissible speed

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

Cant deficiency

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

Cant excess

Cant excess (*C*e) 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.

2.3.8 Necessity for Geometric Design

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

(a) To ensure the smooth and safe running of trains
(b) To achieve maximum speeds
(c) To carry heavy axle loads
(d) To avoid accidents and derailments due to a defective permanent way
(e) To ensure that the track requires least maintenance.
(f) For good aesthetics

2.4 Railway Stations and Yards:

A railway station is that place on a railway line where traffic is booked and dealt with and where trains are given the authority to proceed forward. Sometimes only one of these functions is carried out at a station and accordingly it is classified as a flag station or a block station. In the case of a flag station, there are arrangements for dealing with traffic but none for controlling the movement of the trains. In the case of a block station, a train cannot proceed further without obtaining permission from the next station and traffic may or may not be dealt with.

2.4.1 Purpose of a Railway Station

A railway station is provided for one or more of the following purposes.
(a) To entrain or detrain passengers
(b) To load or unload goods or parcels
(c) To control the movement of trains
(d) To enable trains to cross each other in the case of a single-line section
(e) To enable faster trains to overtake slower ones
(f) To enable locomotives to refuel, whether it be diesel, water, or coal
(g) To attach or detach coaches or wagons to trains
(h) To collect food and water for passengers
(i) To provide facilities for change of engines and crew/staff
(j) To enable sorting out of wagons and bogies to form new trains
(k) To provide facilities and give shelter to passengers in the case of emergencies such as floods and accidents, which disrupt traffic

2.4.2 Selection of Site for a Railway Station

The following factors are considered when selecting a site for a railway station.

Adequate land There should be adequate land available for the station building, not only for the proposed line but also for any future expansion. The proposed area should also be without any religious buildings.

Level area with good drainage The proposed site should preferably be on a fairly level ground with good drainage arrangements. It should be possible to provide the maximum permissible gradient in the yard. In India, the maximum permissible gradient adopted is 1 in 400, but a gradient of 1 in 1000 is desirable.

Alignment The station site should preferably have a straight alignment so that the various signals are clearly visible. The proximity of the station site to a curve presents a number of operational problems.

Easy accessibility The station site should be easily accessible. The site should be near villages and towns. Nearby villages should be connected to the station by means of approach roads for the convenience of passengers.

Water supply arrangement When selecting the site, it should be verified that adequate water supply is available for passengers and operational needs.

Facilities Required at Railway Stations:

The passenger station is the gateway through which people find their way into a town or community. A first impression is a lasting one and, hence, a well designed station building with well-maintained surroundings is important. Whilst service is the main consideration, the type and finish of a station building should be, as far as practicable, in keeping with the best standards of civic amenities available in that area. A large passenger station should provide for facilities corresponding to the anticipated demands of at least the first 20 years of its life, with provisions for future expansion. The facilities required at stations are broadly classified into the following main groups.

Passenger requirements

This includes waiting rooms and retiring rooms, refreshment rooms and tea stalls, enquiry and reservation offices, bathrooms and toilets, drinking water supply, platform and platform sheds, and approach roads.

Traffic requirements

This includes goods sheds and platforms, station buildings, station master's office and other offices, signal and signal cabins, reception and departure lines and sidings, arrangements for dealing with broken down trains, and station equipment.

Locomotive, carriage, and wagon requirements

This includes the locomotive shed, watering or fuelling facilities, turntable, inspection pits, ashpits, ashtrays, etc.

Staff requirements

This includes rest houses for officers and staff, running rooms for guards and drivers, staff canteens, etc.

2.4.3 Requirements of a Passenger Station Yard

The main requirements of a passenger yard are the following.

(a) It should be possible to lower the signals for the reception of trains from different directions at the same time. This facility is particularly necessary at junction stations so that all the trains what are to be connected with each other may be received at the same time.

(b) Unless all trains are booked to stop at the station, it should be possible to run a train through the station at a prescribed speed.

(c) In the case of an engine changing station, an engine coming from or going to a shed should cause minimum interference in the arrival and departure of trains.

(d) An adequate number of platforms should be provided so that all trains can be dealt with at the same time.

(e) There should be convenient sidings where extra carriages can be stabled after having been detached from trains or before their attachment to trains.

(f) There should be provision of facilities for dealing with special traffic such as pilgrim and tourist traffic, parcels in wagon loads, livestock, and motor cars.

(g) Stabling lines, washing lines, sick lines, etc., should be provided as per requirement.

2.5 Block Stations

A block station is a station at which the driver has to obtain an ‘authority to proceed’ in order to enter the next block section. In a railway system that is inclusive of block stations, the entire railway line is divided into convenient block sections of 5 to 10 km and a block station is provided at the end of each block. This system ensures that a suitable ‘space interval’ is provided between running trains so that there are no collisions and accidents. There are three types of block stations.

2.5.1 A class station

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

A class stations are suitable for sections where traffic passes rapidly. It is essential for the driver of the train to have an advance knowledge of the layout of the block station.

Advantages

(a) More economical visa-vis B class stations because of the use of fewer signals.
(b) Ensures the safety of the train because of the provision a warner signal ahead of a home signal.
(c) Trains normally stop within the station limits.

Disadvantages

(a) No shunting is possible once line clear has been granted.
(b) Another clear disadvantage of A class stations, is that a line at the station has to be kept clear up to the starter signal once the line clear signal has been given, and as such the flexibility of working and shunting is restricted.

2.5.2 B class station

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

2.5.3 C class station

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

2.5.4 Non-block Stations or D Class Stations

D class or non-block stations are located between two block stations and do not form the boundary of any block section. No signals are provided at D class stations.

A D class station that serves an outlying siding is called a *DK station*. At such a station, the siding takes off through a crossover, which can be operated only with the help of a key, which in turn is released with the help of a ball token. A D class station that serves no siding is called a *flag station*.

2.5.5 Functional Classification of Stations

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

(a) Halts
(b) Flag stations
(c) Roadside or crossing stations
(d) Junction stations
(e) Terminal stations

2.5.5.1 Halt

A halt is the simplest station where trains can stop on a railway line. A halt usually has only a rail level platform with a name board at either end. Sometimes a small waiting shed is also provided, which also serves as a booking office. There is no yard or station building or staff provided for such types of stations. Some selected trains are allotted a stoppage line of a minute or two at such stations to enable passengers to entrain or detrain. The booking of passengers is done by travelling ticket examiners or booking clerks. A notable example of the halt is a Gurhmukteshwar bridge halt, which is situated on the bank or river Ganga.

2.5.5.2 Flag station

A flag station is more important as a stop-over for trains than a halt and is provided with a station building and staff. On controlled sections, a flag station is equipped with either a Morse telegraph or a control phone, which is connected to one of the stations on either side to facilitate easy communication. A flag station is usually provided with a small waiting hall and booking office, platforms and benches, and arrangements for drinking water. Sometimes a flag station is also provided with a siding for stabling wagons booked for that station.

2.5.5.3 Wayside or crossing station

After a flag station comes the wayside or crossing station. While a flag station has arrangements for dealing with traffic but none for controlling the movement of the trains, a crossing station has arrangements for controlling the movement of trains on block sections. The idea of a crossing 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.

2.5.5.4 Junction stations

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.

2.6 Types of 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.

2.6.1 Coaching yard

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.

2.6.2 Goods yard

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.

2.6.3 Marshalling yard

A goods yard which deals with the sorting of goods wagons to form new goods trains is called a marshalling yard.

2.6.4 Locomotive yard

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.

2.6.5 Sick line yard

Whenever a wagon or coach becomes defective, it is marked ‘sick’ and taken to sick lines. This yard deals with such sick wagons. Adequate facilities are provided for the repair of coaches and wagons, which include examination pits, crane arrangements, train examiner’s office and workshop, etc. A good stock of spare parts should also be available with the TXR (train examiner) for repairing defective rolling stock.

2.7 Marshalling Yard

The marshalling yard is a yard where goods trains are received and sorted out, and new trains are formed and finally dispatched to various destinations. 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 marshalled, 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 an route at wayside stations.

2.7.1 Principles of design:

A marshalling yard should be so designed that there is minimum detention of wagons in the yard and as such sorting can be done as quickly as possible. These yards should be provided with the necessary facilities such as a long shunting neck, properly designed hump, braking arrangement in the shape of mechanical retarders, etc., depending upon the volume of traffic. The following points should be kept in mind when designing a marshalling yard.

(a) Through traffic should be received and dispatched as expeditiously as possible. Any idle time should be avoided.

(b) There should be a unidirectional movement of the wagons as far as possible.

(c) There should be no conflicting movement of wagons and engines in the various parts of the yard.

(d) The leads that permit the movement of wagons and train engines should be kept as short as possible.

(e) The marshalling yard should be well lighted.

(f) There should be adequate scope for the further expansion of the marshalling yard.

2.7.2 Types

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.

2.7.2.1 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.

2.7.2.2 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.

2.7.2.3 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. These are, however, only recommended gradients and the final gradient for a particular yard is decided after a test run of the trains over the humps, taking into consideration the rolling quality of different types of wagons and the spacing between successive groups of wagons.

The topography of the location of the yard also plays an important role in deciding the gradient.

2.7.3 Hump

The hump should be designed to meet the following objectives.

(a) It should be such that even the wagon whose movements are affected the worst by the most adverse weather conditions can clear the fouling mark, when sent to the outermost siding.

(b) It should be such that a successive group of wagons are separated from each other to the extent that it enables the point between them to be operated upon so that the wagons can be sent to various sidings.

(c) The hump should be such that the speed of the wagons is so regulated that there is no damage to the wagons when they bump against each other in the sorting lines.

2.7.4 Sorting yard

The number of lines to be included in the sorting yard depends upon the number of destinations for which the trains are to be assembled. The length of each sorting line is about 15 to 20% more than that of a normal train so that there is provision of some space behind the wagons. The layout of the sorting yard may be of the ladder or the balloon type. The speed of the wagons is controlled by hand brakes while the skids and the mechanical retarders are controlled by manual and mechanical means, respectively.

2.7.5 Departure yard

The number of lines to be included in a departure yard depends upon the number of trains proposed to be dispatched from the yard and on the frequency of their departure. Some engineers feel that there is no need for a separate dispatching yard because it unnecessarily increases the length of the marshalling yard. According to them, trains should be dispatched straight from the sorting lines. This arrangement, however, runs into problems if the departure of the trains is delayed on account of operational reasons.

2.7.6 Functions of Marshalling Yards:

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.

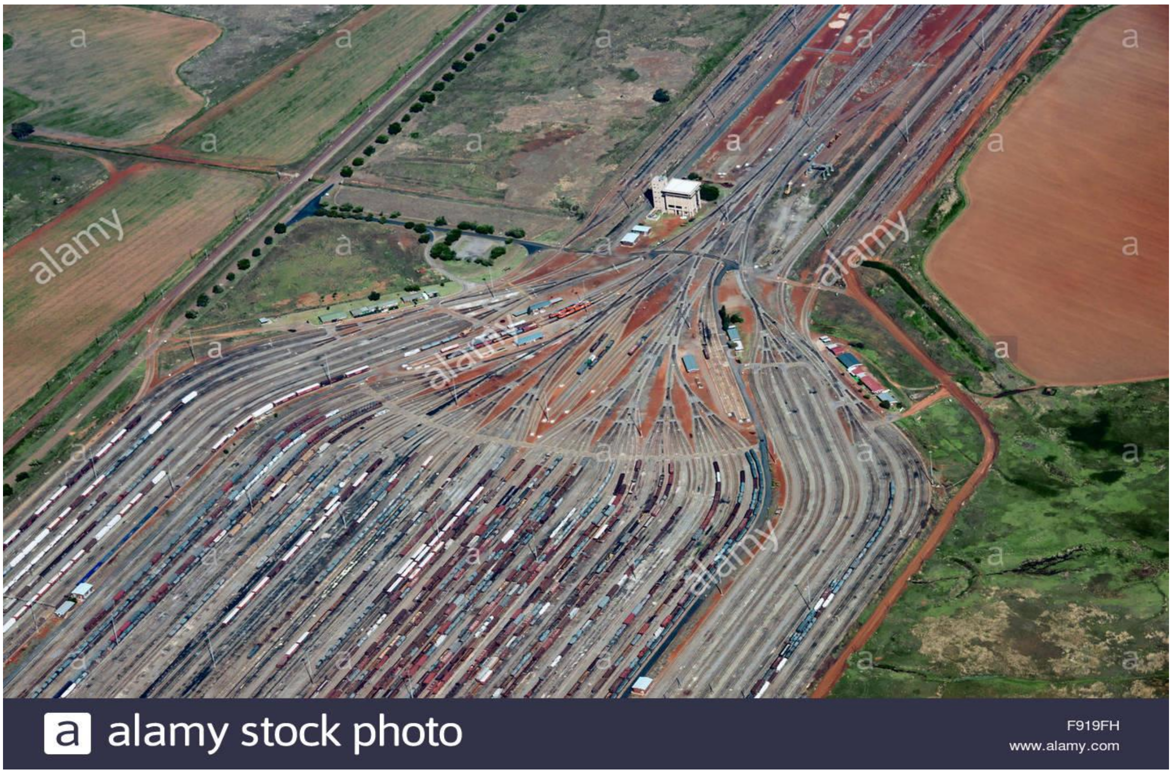


FIG. MARSHALLING YARD

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E-NOTES

SUBJECT: TRANSPORT ENGINEERING 2 **SUBJECT CODE: CE-310B**

COURSE- BTECH **BRANCH: CIVIL ENGINEERING**

SEMESTER 6TH **CHAPTER NAME: RAILWAYS UNIT 3**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

Signalling and Interlocking:

3.1 Introduction

The purpose of signalling and interlocking is primarily to control and regulate the movement of trains safely and efficiently. Signalling 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. Signalling 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 signalling 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. The history of signalling goes back to the olden days when two policemen on horseback were sent ahead of the train to ensure that the tracks were clear and to regulate the movement of the trains. In later years, policemen in uniform were placed at regular intervals to regulate the movement of trains.

Railway signalling in its present form was introduced for the first time in England in 1842, whereas interlocking was developed subsequently in 1867.

3.2 Objectives of Signalling:

The objectives of signalling are as follows.

(a) To regulate the movement of trains so that they run safely at maximum permissible speeds.
(b) To maintain a safe distance between trains that are running on the same line in the same direction.

(c) To ensure the safety of two or more trains that have to cross or approach each other.
(d) To provide facilities for safe and efficient shunting.
(e) To regulate the arrival and departure of trains from the station yard.
(f) To guide the trains to run at restricted speeds during the maintenance and repair of tracks.
(g) To ensure the safety of the train when it comes in contact with road traffic at level crossings.

3.3 Classification of Signals:

Railway signals can be classified based on:

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.

3.3.1 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 requisite action.

3.3.2 Visible Signals

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

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

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

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

Stop signals

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

3.3.3 Fixed Signals

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

Semaphore signals

The word 'semaphore' was first used by a Greek historian. 'Sema' means sign and 'phor' means to bear. A semaphore signal consists of a movable arm pivoted on a vertical post through a horizontal pin.

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

Coloured light signals

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

Calling-on signal

This consists of a small arm fixed on a home signal post below the main semaphore arm. When the main home signal is in the horizontal (on) position and the calling-on signal is in on inclined (off) position, it indicates that the train is permitted to proceed cautiously on the line till it comes across the next stop signal.

Thus the calling-on signal is meant to 'call' the train, which is waiting beyond the home signal.

The calling-on signal is useful when the main signal fails, and in order to receive a train, an authority letter has to be sent to the driver of the waiting train to instruct him/her to proceed to the station against what is indicated by the signal. In big stations and yards, the stop signals may be situated far off from the cabin and the calling-on signal expedites the quick reception of the train even the when signal is defective.

Co-acting signal

In case a signal is not visible to the driver due to the presence of some obstruction such as an overbridge or a high structure, another signal is used in its place, preferably on the same post. This signal, known as the co-acting signal, is an exact replica of the original signal and works in unison with it.

Repeater signal
In cases where a signal is not visible to the driver from an adequate distance due to sharp curvature or any other reason or where the signal is not visible to the guard of the train from his position at the rear end of a platform, a repeater signal is provided at a suitable position at the rear of the main signal. A repeater signal is provided with an R marker and can be of the following types.
(a) A square-ended semaphore arm with a yellow background and a black vertical band.
(b) A coloured light repeater signal.
(c) A rotary or disc banner type signal.

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

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

Outer signal
This is the first stop signal at a station, which indicates the entry of a train from a block section into the station limits. This signal is provided at an adequate distance beyond the station limits so that the line is not obstructed once the permission to approach has been given. It is provided at a distance of about 580 m from the home signal. The signal has one arm but has a warner signal nearly 2 m below on the same post.

When the outer signal is in the 'on' (or stop) position, it indicates that the driver must bring the train to a stop at a distance of about 9 m from the signal and then proceed with caution towards the home signal. If the outer signal is in the 'off' (or proceed) position, it indicates that the driver does not need to reduce the speed of the train if the home signal is also in the 'off' (or proceed) position, which is indicated by the 'off' position of the warner.
As the outer signal controls the reception of trains, it comes under the category of reception signals.

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

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

3.4 Signalling Systems
The entire signalling system can be classified into two main categories.
(a) Mechanical signalling system
(b) Electrical signalling system

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

(a) Operated units such as signals and points
(b) A transmission system such as single- or double-wire transmission or electrical transmission
(c) Operating units such as levers and press buttons
(d) Monitoring units such as detectors, treadle bars, and track circuiting

3.4.1 Mechanical Signalling System

The mechanical signalling system mostly involves signals and points as explained in this section.

Signals

The signals used in a mechanical signalling system are semaphore signals. These signals are operated by means of either a lower quadrant or an upper quadrant signalling system.

Lower quadrant signalling system

This system of signalling was designed so that the semaphore arm of the signal could be kept either horizontal or lowered. The lower left-hand quadrant of a circle is used for displaying a semaphore indication to the driver of a train. This concept was possibly developed based on the left-hand driving rules applicable on roads in the UK and in India.

Upper quadrant signalling system

In lower quadrant signalling, the semaphore arm of the signal can only take two positions, namely, horizontal or lower; it is not possible to include a third position for the semaphore arm, such as vertically downward position, due to design as well as visibility problems, since as the semaphore arm would, in that case, be super imposed on the signal post. Due to this limitation, the upper quadrant system was developed, which can display more than two aspects. In this system, it is possible to incorporate three positions of the semaphore arm, namely, (a) horizontal, (b) inclined at an angle of about 45° above the horizontal level, and (c) vertical, i.e., inclined at an angle of 90° above the horizontal level.

3.4.2 Electrical Signalling System

The electrical signalling system is progressively replacing the mechanical signalling system on Indian Railways, especially with the coming up of railway electrification projects. The main reasons behind this are as follows:

(a) There are a number of movable parts in the mechanical signalling system such as rods, wires, and cranks, which cause heavy wear and tear, frictional losses, and many of these parts can be sabotaged by unauthorized persons.
(b) The arms of the semaphore signals used in mechanical signalling afford poor visibility during the day. The night indications of these signals are also not satisfactory.
(c) The operational time of the mechanical signalling system is much greater than that of the electrical signalling system.

In the electrical signalling system, electrical energy is used for displaying signals. The transmission of power is done electrically and the units are operated by electrical push buttons while system is monitored by electrical systems.

3.5 Absolute block system

This system involves dividing the entire length of the track into sections called *block sections.* A block section lies between two stations that are provided with block instruments (explained later). The block instruments of adjoining stations are connected through railway lines and a token can be taken from the block instrument of a particular station with the consent of both the station masters.
In the absolute block system, the departure of a train from one station to another is not permitted until and unless the previous train has completely arrived at the next station, i.e., trains are not permitted to enter the section between two stations at the same time. The procedure by which this system is maintained is known as the *lock and block* procedure. The instruments used for this purpose are known as block instruments.

Block instruments Each station has two block instruments; one for the station ahead and the other for the previous station. The block instruments of two adjacent stations are electrically interconnected. These block instruments are operated with the consent of the station masters of the stations on either end of the block section, who are also responsible for giving the line clear indication. Normally a round metal ball called a 'token' is taken as the authority to proceed in a block section. This token is contained inside the block instrument.
There following different types of block instruments are used on Indian Railways depending upon various requirements.

3.5.1 Single-line token instruments

These are meant for stations with single lines. No train is authorized to enter the block section without a token. The token can be taken out of the block instrument of the departure station only when the station master turns the handle of the block instrument towards the end labelled 'Train going to side'. This can be done only with the consent of the station master of the station on the other side of the block section, who turns the handle of his or her block instrument towards the end labelled 'Train coming from side'. It is not possible to turn the signal permitting the entry of the train into the block section off until the
handle of the block instrument has been turned towards the 'Train going to side' label. In this situation, the handles of both these instruments get locked in the last operated position and it is not possible to normalize both the block instruments until the train arrives at the next station and the token has been inserted into the block instrument of that station. This phenomenon of keeping the block instruments locked and releasing them only during the passage of a train is the previously mentioned lock and block procedure.

3.5.2 Single-line token less block instruments

There have been occasions when a train has had to be brought to a halt because of the driver misplacing the token, causing the trains to get detained for long periods. In order to avoid such occurrences, token less block instruments have been developed. The same principle as that of the block system is followed here but without the use of a token. The last stop signal permitting the entry of the train into the block section, which is normally the advanced starter signal, is interlocked with the block instrument in such a way that it is not possible to turn this signal off unless the block instrument has obtained the line clear command.

3.6 Automatic block system

In the space interval system, clearing a long block section is a protracted event and the subsequent train has to wait till the preceding train clears the entire block section. This impairs the capacity of the section with regard to the number of trains it can clear at a time. In order to accommodate more trains in the same section, the block section is divided into smaller automatic block sections. This is particularly done for sections that are long and have turned into bottlenecks. The essentials of an automatic block system on a double line are as follows.

(a) The line should be provided with continuous track circuiting.
(b) The line between two adjacent block stations may, when required, be divided into a series of automatic block signalling sections, entry into each of which will be governed by a stop signal.
(c) The track circuits should control the stop signal governing the entry into an automatic block signalling section in the following manner.

3.7 Interlocking

Interlocking is a device or a system meant to ensure the safety of trains. With the increase in the number of points and the signals and introduction of high speeds, it has become necessary to eliminate human error, which would otherwise lead to massive losses of life and property.

The points and signals are set in such a way that the cabin man cannot lower the signal for the reception of a train unless the corresponding points have been set and locked. The signal is thus interlocked with the points in a way that no conflicting movement is possible and the safety of trains is ensured.

Interlocking can, therefore, be defined as an arrangement of signals, points, and other apparatus so interconnected by means of mechanical or electrical locking that they can be operated in a predetermined sequence to ensure that there is no

conflicting movement of signals and points and trains run safely.
The signal and interlocking system is so designed that the failure of any equipment results in the turning on of the signal, thus ensuring train safety.

3.7.1 Essentials

Lever frames and other apparatus provided for the operation and control of signals, points, etc., must be so interlocked and arranged as to comply with the following essential regulations.

(a) It should not be possible to turn a signal off unless all points for the line on which the train is to be received are correctly set, all the facing points are locked, and all interlocked level crossings are closed and inaccessible to road traffic.

(b) The line should be fully isolated before the signal is turned off, i.e., no loose wagons should be able to enter this line.

(c) After the signal has been turned off, it should not be possible to make adjustments in the points or locks on the route, including those in the isolated line. Also, no interlocked gates should be released until the signal is replaced in the ‘on’ position.

(d) It should not be possible to turn any two signals off at the same time, as this can lead to conflicting movements of the trains.

(e) Wherever feasible, the points should be so interlocked as to avoid any conflicting movement.

3.7.2 Standards

The speed of a train depends on a number of factors such as the haulage capacity of the locomotive, the fitness of the track, the fitness of the rolling stock, the load of the train, etc., and the speed for a particular section is determined based on all these factors. Depending upon the maximum speeds permitted in a section, the stations are interlocked in keeping with the prevalent standards, and signalling equipment and other facilities are provided accordingly.
There are four standards of interlocking based on the maximum permissible speeds prevailing on Indian Railways. These refer to the speeds over the main line with respect to the facing points and the yard.

3.7.3 Methods

There are basically two methods of interlocking as explained below:

3.7.3.1 Key interlocking

Key interlocking is the simplest method of interlocking and still exists on branch lines of small stations on Indian Railways. The method involves the manipulation of keys in one form or the other. This type of interlocking is normally provided with standard I interlocking with a speed limit below 50 km/h. The simplest arrangement of key interlocking is accomplished in the following manner.

(a) Take the example of a station with a main line and a branch line. The point can be set either for the main line or branch line.

(b) The point has two keys. The first is key A, which can be taken out when the point is set and locked for the main line. Similarly, key B can be taken out when the point is set and locked for the loop line. At any given time either key A or key B can be taken out, depending upon whether the route is set for the main line or the loop line.

(c) The lever frame operating the signals is provided with two levers. The lever concerning the main line signal can be operated only by key A and similarly the branch line signal lever can be operated only by key B.

(d) If the train is to be received on the main line, the points are set and locked for the main line and key A is released. This key is used for unlocking the main line signal lever, thus lowering the signal for the main line. Since key A cannot be used for interlocking and lowering the branch line signal, only the appropriate signal can be turned off. This type of interlocking is called *indirect locking*.

In case more than one point is to be operated, the key released at the first point is used to unlock and operate the second point and so on. The key released at the last point can then be used for unlocking the lever operating the appropriate signal. This type of interlocking is also known as *succession locking* and is also used for checking conflicting movements in shunting operations. There are other methods of interlocking with the help of keys, but all of them involve considerably lengthy trips from the point to the signal levers and from point to point, thereby leading to delays. Such arrangements are, therefore, satisfactory only for stations that handle very light traffic.

3.7.3.2 Mechanical interlocking

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 move 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.

3.8 Modern Signalling Installations

Advancements in electrical engineering and electronics have greatly contributed to the modernization of signalling installations, leading to better safety, increased speeds, and quicker movement of trains. Some of these modern signalling installations are described below:

3.8.1 Panel interlocking

In panel interlocking, all points and signals are operated electrically from a central location and the switches for operating these points and signals are mounted on a panel, which also bears the diagram of the yard layout. Electrical interlocking of these points and signals is achieved by means of relays. The main advantage of panel interlocking is that the various functions of all the points and signals, even though the same cover great distances, can be centrally controlled, thereby eliminating the need for multi-cabin operations of the same. With the elimination of inter cabin control and slotting, the time that is normally lost in coordination is saved and the line capacity increases so that a greater number of trains can be run by a smaller operating staff.

3.8.2 Route relay interlocking

Route relay interlocking is an improvement over panel interlocking. Unlike panel interlocking, where each point in the route has to be individually set with a respective switch and where the clearance of the signal is obtained by operating the signal switch, route relay interlocking involves the use of only a pair of switches to perform all these operations automatically. Using this pair of switches, the desired route for the train is set automatically by putting all the points along the route in their desired positions. The required signal is then cleared automatically too. During this operation, it is also ascertained that there is no conflicting movement of the trains in progress or in the offing and also that the route is clear for the movement of a train, including at the overlap. One of the essential requirements for this is that the entire yard has got to be track circuited. The condition of the track circuits and the various indications of all the signals on the route are mirrored on the panel that carries the diagram of the yard. By looking at these indications, the panel operator can easily discern which portion of the track is clear or occupied and which signal has been cleared for the movement of the train. Once the route is set to allow the passage of a train, the relevant portion of the diagram on the panel gets illuminated with white lights.

The lights turn red when the track is occupied by the train. When the train has cleared the track, the lights automatically go off.

Route relay interlocking is very useful in busy yards such as the Mumbai suburban section, where traffic density is very heavy. As route relay interlocked yards are fully track circuited, they ensure complete safety with regard to the movement of trains.

3.9 Centralized train control

The operation of all the points and signals of the various stations of a section is centralized at one place in such a system. Thus all the points and signals are controlled by a single official called the centralized train control (CTC) operator. A CTC operator virtually takes over the work of the station masters of several individual stations and operates all the points and signals at a station through remote control.

The CTC panel is normally provided at a central location and controls various stations up to a distance of about 120 km on either side. There is a separate panel provided for the operator, which depicts the entire section, including the points, crossings, signals, etc. The signals, routes, points, etc., are operated from the panel by means of separate knobs. This panel also depicts whether the various tracks are occupied or otherwise.

In a CTC system, panel interlocking is provided at all stations, which ensures complete safety. The CTC operator sends commands to the station equipment in the form of coded electric pulses by pressing the relevant buttons. The station equipment receives these commands, and sets the points to the desired position, and clears the appropriate signals. After the task is completed, indication signals are automatically sent back to the CTC panel in the form of coded electric pulses and the positions of the points and signals are indicated on the panel. In the route interlocking system, instructions regarding the running of trains, arrangement of crossings, etc. are issued by the control office through phone calls placed to various station masters and the actual control of the movement of the trains between the stations is exercised by the station masters. In the CTC system, all the functions of the controller and the station masters are carried out by the CTC operator, who is always aware of the position of all the trains in the section through the illuminated panel and who can remotely operate the various signals and points at all the stations.

He or she can, therefore, make judicious plans regarding how the trains will move forward and how they will cross each other. Moreover, the automatic block system is always adopted in conjunction with CTC with the result that the number of trains in a block section can also be increased. The major advantages of the CTC system are enumerated below.

(a) There is considerable saving in the amount of time taken by trains to complete a run and as such the line capacity of the section is increased. In fact, with the introduction of CTC the necessity of doubling the track can be overlooked.

(b) No trained station masters, points men, etc. are required at the various stations. The CTC operator does all the work from the central panel. Thus there is considerable reduction in the number of skilled staff members required.

(c) The system has the potential to detect any defects in the track.

3.10 Automatic warning system

Any amount of safety features incorporated in signalling and interlocking equipment will be of no use if the driver ignores a danger signal. The automatic warning system (AWS) is a device that triggers the automatic application of brakes if the signal is indicating danger and the driver has not taken any action. The system consists of a track device located at a desirable braking distance at the rear end of the first stop signal. The track device is activated when the signal indicates danger and is ineffective when the signal is ‘clear’. When the locomotive passes over the track device with the signal indicating that the line ahead is clear, nothing happens.
However, if the signal happens to be indicating danger, a red lamp gets lighted as soon as the locomotive passes over it followed by the ringing of an alarm bell. If the driver presses the acknowledgement button and applies the brake, the alarm stops ringing and no further action is taken by the AWS. If, on the other hand, no action is taken by the driver, the bell continues to ring. The emergency brakes are then applied automatically and the train is brought to a stop.

3.11 Last vehicle check device

One of the important features of the absolute block system is that a train should not be allowed to enter the block section unless the last train has arrived at the station from either end of the block section. This must be verified by the operator responsible for operating the block instrument by observing the last vehicle board or last vehicle light. It has been observed that in quite a few cases the operator has been found careless in certifying the last vehicle. To eliminate human error, a device known as the *last vehicle check device* has been developed. This consists of a passive equipment that the guard hangs on the last vehicle of the train. Each station is provided with a corresponding active equipment that emits waves of a predetermined frequency.

This equipment is fitted at the entrance of each station. The coupling of the instruments takes place whenever the last vehicle passes by the active equipment, which is sensed by the last vehicle check device (LVCD). The operator receives an indication of the same and can now close the block instrument and issue a fresh line clear. The last vehicle check device eliminates human error in ensuring the safe arrival of the complete train.

3.12 Modernization of Railways and high speed trains:

3.12.1 Introduction

Indian Railways, in keeping pace with the advanced railways of the world, has been modernizing its railway system for quite some time. The maximum permissible speed on the BG sections of Indian Railways was increased to 120 km/h by first introducing it on the Delhi–Howrah route in 1969. This increase in speed was possible after carrying out extensive investigations and trials on the Rajdhani route using a WDM-4 locomotive and all-coiled coaches. The study was based on the fundamental concept that safety and comfort at high speeds depends upon the interaction of the track and the vehicle. If the suspension system of the rolling stock is very good, then even though track maintenance may be of a comparatively average quality, a reasonable level of comfort will still be achieved. To a limited extent, track stability can be economically introduced on Indian Railways without carrying out major changes in the track structure, by simply selecting better locomotives and rolling stocks and adhering to a slightly higher standard of track maintenance. It was for this reason that the Rajdhani Express was hauled by a WDM-4 locomotive and included all-coiled coaches. The speed of the train, which was originally 120 km/h, has been increased to 140 km/h and Indian Railways is now planning to increase the speed to 160 km/h.

Similarly, in the case of meter gauge, the long existent limit of 75 km/h has finally been overcome and trains consisting of a YDM-4 locomotive and all-coiled Integral Coach Factory (ICF) coaches are running at speeds of up to 100 km/h since December 1997.

3.12.2 Modernization of 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 signalling 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.

(a) Use of heavier rail sections such as 52 kg/m and 60 kg/m and the use of resistant rails for heavily used sections so as to increase the life of the rails.

(b) Use of curved switches of 1 in 16 and 1 in 20 type for smoother arrival at yards.

(c) Use of prestressed 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.

(d) Use of long welded rails and switch expansion joints to ensure a smooth and fast rail journey.

(e) Modernization of track maintenance methods to include mechanized maintenance, measured shovel packings, etc., in order to ensure better track geometry, to facilitate high speeds and smooth travel.

(f) 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.

(a) Use of better designed all-coiled, anti-telescope ICF coaches with better spring arrangements and better braking systems for safe and smoother rail travel.
(b) Provisions of universal couples to ensure uniformity in the coupling of the coaches.
(c) Introduction of diesel and electric traction in order to haul heavier loads at faster speeds.
(d) Introduction of modern signalling techniques to enable trains to move at high speeds without any risks.
(e) Setting up of a management information system for monitoring and moving freight traffic in order to avoid idle time and increase productivity.
(f) Computerization of the train reservation system to avoid human error and provide better customer service for reservation of berths.
(g) 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.

3.12.3 Effect of High-speed Track

Investigations carried out in connection with high-speed trains have revealed that an increase in speed does not necessarily result in a corresponding increase in the deformation and stresses in track components, which necessitates the use of a heavier track structure. The loads, deformations, and stresses in the track components were found to be augmented as a result of the incongruous movement of vehicles on the track including pitching, rolling, bouncing, etc., which occur when the track is poorly maintained. Therefore, it is possible to operate the same

vehicles at a higher speed on a given track structure without imposing any additional loads and stresses, provided that the standards of maintenance of the track and the vehicles are sufficiently improved so as to control these inhibiting movements of the vehicle when it runs at higher speeds. The existing track structure on the Rajdhani route is considered to be of adequate standard for speeds reaching as high as 120 to 140 km/h.
To achieve still higher speeds of the order of 160 to 200 km/h, the standard of maintenance needs to be very high, as very close track tolerances will have to be maintained. Maintaining the existing tracks at such tolerance limits may be uneconomical and may necessitate the adoption of an improved track structure, which can be maintained at closer tolerance limits at a comparatively low costs. The modern track structure, consisting of long welded rails with concrete sleepers, elastic fastenings, and ballast less tracks may well fulfil this requirement. The cost of this modern track may be comparatively high, but its maintenance will involve limited expenditure.

3.12.4 Vehicle Performance on Track

When judging the performance of a high-speed vehicle on the track, it is ascertained that the following requirements are fulfilled.
(a) At the defective locations in the track, the variations in the vertical and lateral wheel loads should not reach a level where the wheels can get derailed because of the incidence of mounting.
(b) At defective portions of the track, the variations in the vertical and lateral wheel loads should not reach a level where they can lead to derailment as of a result of the distortion to the track.
(c) It should be ensured that the passengers are generally comfortable while the vehicle plies on the track and that goods are carried without any damage.
(d) In the case of diesel and electric locomotives, it is specified that a lateral force lasting more than 2 m should not normally exceed 40% of the axle load plus 2 t. The values of acceleration recorded in the cab at locations should, as far as possible, be limited to 0.3g, both in the vertical and the lateral direction.

A peak value of 0.35g may be permitted in case the records do not indicate a significant tendency of this value to be repeated. The ride index is calculated for the purpose of comfort analysis, based on the lateral and vertical acceleration values obtained from acceleration output graphs. The ride index should normally not be greater than 4; a value of 3.75 is preferred.

3.12.5 Underground Railways

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

An underground railway system normally uses ‘electric traction’, as steam and diesel tractions produce smoke and lead to the pollution of the environment, which in this case becomes particularly hazardous since these railways are underground. Proper arrangements are also made for the drainage of underground railways as the low-lying areas in which they are constructed are likely to get flooded during the rains. Such underground railways have been constructed in Kolkata and Delhi and in other countries around the world.

The main advantages and limitations of underground railways are as follows.

Advantages

(a) Trains can run fast and unobstructed in an underground railway system as there are no road crossings or other similar problems.

(b) As the trains move at incredible speeds, underground railways can deal with a very high concentration of human traffic.

(c) There is no wastage of land and a large area of the city, which would have otherwise been used for surface railways, remains available for other utilities.

(d) Provides safety from aerial attacks, particularly during war.

Limitations

(a) The underground railway system is a very costly arrangement and a heavy financial backing is required. The cost may vary anywhere from Rs 30 million to 100 million per km, depending upon the geographical features and other conditions.

(b) Special attention needs to be given to the drainage as well as proper ventilation of underground railways.

(c) During construction, the residents of the city are greatly inconvenienced as excavation work is normally carried out throughout the city. The water supply, electricity supply, and sewerage system of the city are also affected, as the diversion of many of these services is required during the constructional phase.

3.13 Railway Tunnelling

3.13.1 Introduction

A tunnel can be defined as an underground passage for the transport of passengers, goods, water, sewage, oil, gas, etc. The construction of a tunnel is normally carried out without causing much disturbance to the ground surface. The history of tunnels is very old. The first tunnel was constructed about 4000 years ago in Babylon to connect two buildings. The first railway tunnel in the world was constructed at the end of the nineteenth century to connect Switzerland and Italy. The cross section of the tunnel was in the shape of a horseshoe and its length was about 20 km. On Indian Railways, the first tunnel was constructed near Thane on Central Railways known as the *Parsik tunnel*. It is the longest railway tunnel of India with a length of about 1317 m.

3.13.2 Necessity/Advantages of a Tunnel

The necessity of constructing a tunnel may arise because of one of the following considerations.
(a) A tunnel may be required to eliminate the need for a long and circuitous route for reaching the other side of a hill, as it would considerably reduce the length of the railway line and may also prove to be economical.
(b) It may be economical to provide a tunnel instead of a cutting, particularly in a rocky terrain. Depending upon various factors, a rough calculation would indicate that for a small stretch of land the cost of constructing a tunnel is equal to the cost of a cutting in a rocky terrain.
(c) In hills with soft rocks, a tunnel is cheaper than a cutting.
(d) In metropolitan towns and other large cities, tunnels are constructed to accomodate underground railway systems in order to provide a rapid and unobstructed means of transport.
(e) A tunnel constructed under a river bed may sometimes prove to be more economical and convenient than a bridge.
(f) In the case of aerial warfare transportation through tunnels provides better safety and security to rail users compared to a bridge or deep cutting.
(g) The maintenance cost of a tunnel is considerably lower than that of a bridge or deep cutting.

However, the construction of tunnels is also disadvantageous in certain ways, as enumerated here.
(a) The construction of a tunnel is costly as it requires special construction machinery and equipment.
(b) The construction of a tunnel involves the use of sophisticated technology and requires experienced and skilled staff.

(c) It is a time-consuming process.

3.13.3 Tunnel Alignment and Gradient

A precise and detailed survey is necessary before setting the alignment of a tunnel on the ground. A small error in setting the alignment would result in the two ends never meeting at all. When starting work, both the ends of the tunnel as well as the centre line are marked with precision on the ground so that the correct length of the tunnel can be determined. An accurate survey is then carried out to ensure that the centre line of the alignment and the levels are transferred properly to their underground positions.

The following points require special attention when deciding the alignment and gradient of a tunnel.

(a) The alignment should be straight as far as possible since normally such a route would be the shortest and most economical.

(b) The minimum possible gradient should be provided for a tunnel and its approaches.

(c) Proper ventilation and adequate lighting should be provided inside the tunnel.

(d) The side drains in a tunnel should be given a minimum gradient of 1 in 500 for effective drainage. In longer tunnels, the gradient should be provided from the centre towards the ends for effective and efficient drainage.

3.13.4 Size and Shape of a Tunnel

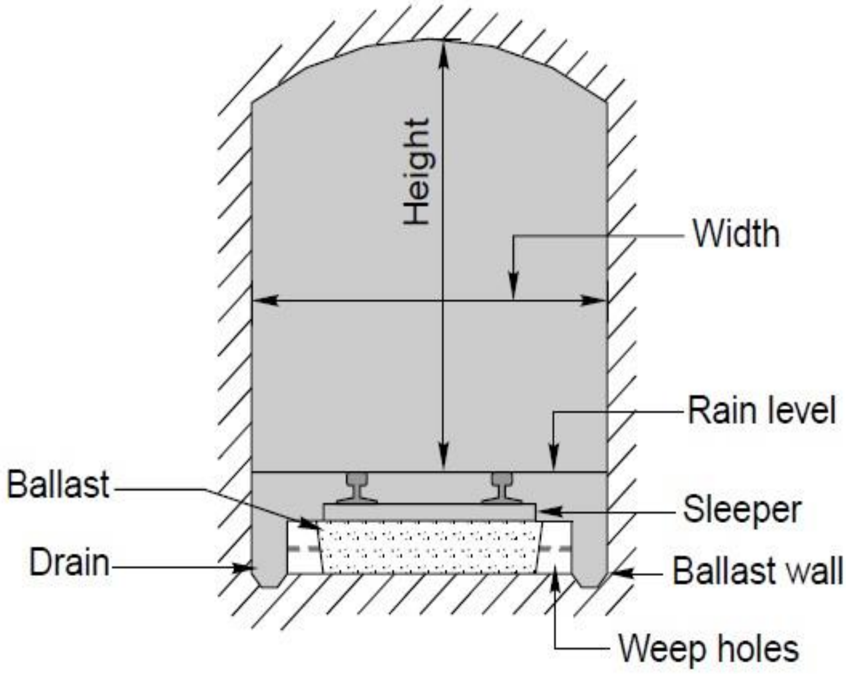
The size and shape of a tunnel depend upon the nature and type of ground it passes through and also on whether it is designed to carry a single or a double railway line. The shape of a tunnel should be such that the lining is able to resist the pressures exerted by the unsupported walls of the tunnel excavation.

If the ground is made up of solid rock, then the tunnel can be given any shape. Tunnels in rocky terrains are generally designed with a semicircular arch with vertical sidewalls. In the case of soft ground such as that consisting of soft clay or sand, the pressure from the sides and the top must be resisted. A circular tunnel is generally best suited for resisting both internal and external forces regardless of the purpose for which the tunnel is used. Theoretically, a circular section provides the largest cross-sectional area for the smallest diameter, which provides greater resistance to external pressure. But this type of cross section is more useful for drains carrying sewage and fluids and for aquaducts built for irrigation purposes.

For railway track, the circular portion at the bottom of the tunnel has to be levelled in order to lay the track and facilitate the easy removal of muck and placing of concrete.

Shape and purpose of tunnels

Shape	Purpose
Circular	Water and sewage
Elliptical	Water and sewage mains
Horseshoe	Roads and railways
Arched roof with vertical walls	Roads and railways
Polycentric cross section	Roads and railways



A typical cross section of a tunnel

3.13.5 Methods of Tunnelling

There are various methods of tunnelling. The selection of a method depends upon the size of the bore, the condition of the ground, the equipment available, and the extent to which timbering is required. Tunnelling may be basically divided into two main groups.

(a) Tunnelling in hard rocks

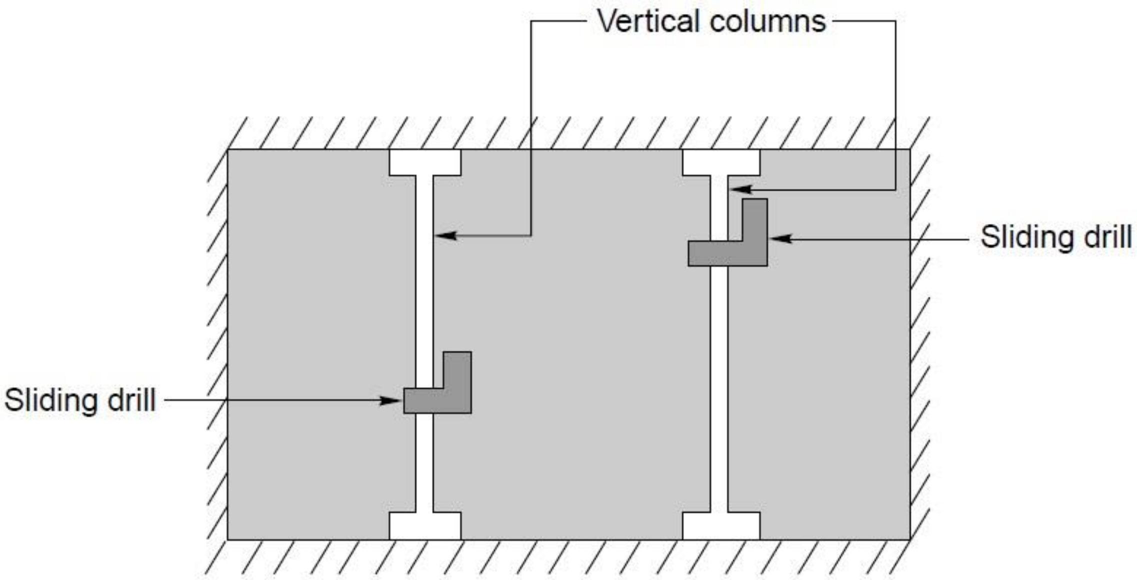
(b) Tunnelling in soft rocks

3.13.5.1 Tunnelling in Hard Rocks

The following methods are generally employed for tunnelling in hard rocks.

Full face method

The full face method is normally selected for small tunnels whose dimensions do not exceed 3 m. In this method, the full face or the entire facade of the tunnel is tackled at the same time. Vertical columns are erected at the face of the tunnel and a large number of drills mounted or fixed on these columns at a suitable height. A series of holes measuring 10 mm to 40 mm in diameter with about 1200 mm centre-to-centre distance are then drilled into the rock, preferably in two rows. These holes are charged with explosives and ignited. Next the muck is removed before repeating the process of drilling holes.



Full face method

Advantages

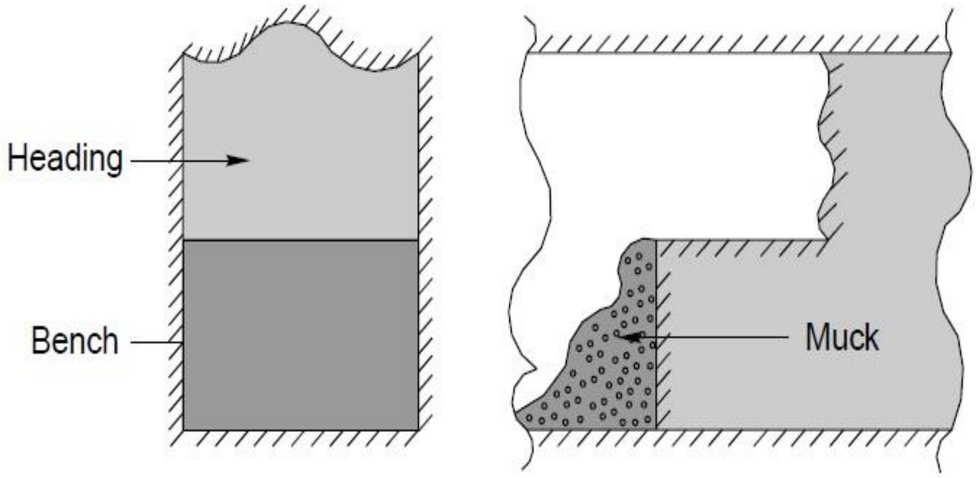
(a) Since an entire section of the tunnel is tackled at one time, the method is completed expeditiously.
(b) Mucking tracks, which are tracks used for collecting muck, can be laid on the tunnel floor and extended as the work progresses.
(c) With the development of the 'jumbo' or drill carriage, this method can be used for larger tunnels too.

Disadvantages

(a) The method requires heavy mechanical equipment.
(b) It is not very suitable for unstable rocks.
(c) It can normally be adopted for small tunnels only.

Heading and bench method

In this method, the heading (top or upper half) of the tunnel is bored first and then the bench (bottom or lower half) follows. The heading portion lies about 3.70 m to 4.60 m ahead of the bench portion. In hard rock, the drill holes for the bench are driven at the same time as the removal of the muck. The hard rock permits the roof to stay in place without supports.



Heading and Bench method

Advantages

(a) The work of drilling of holes for the explosives and the removal of muck can progress simultaneously.

(b) This method requires the use of lower quantities of gunpowder than the full face method.

Drift method

A drift is a small tunnel measuring 3 m × 3 m, which is driven into the rock and whose section is widened in subsequent processes till it equates that of the tunnel. A number of drill holes are provided all around the drift and these are filled up with explosives and ignited so that the size of the drift expands to become equal to the required cross section of the tunnel.

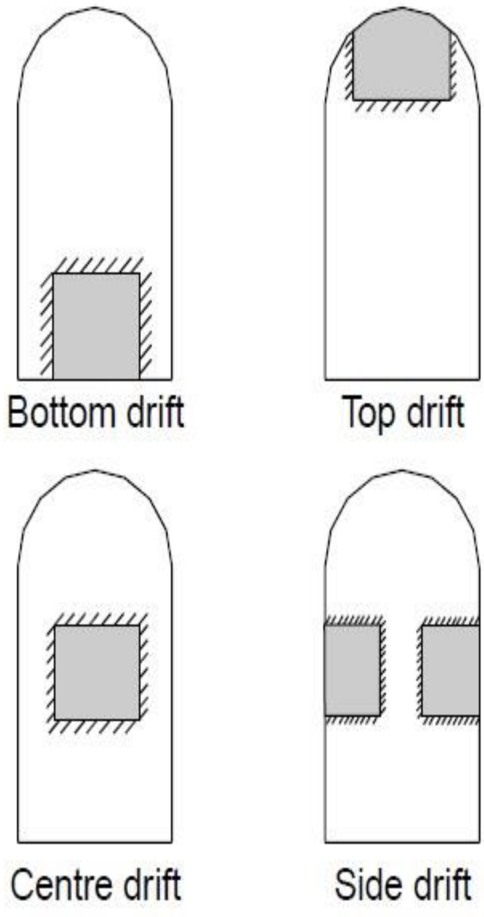
The position of the drift depends upon local conditions; it may be in the centre, top, bottom, or side. Field experience has shown that the central drift is the best choice, as it offers better ventilation and requires lower quantities of explosives. The side drift, however, has the advantage that it permits the use of timber to support the roof.

Advantages

(a) If the quality of the rock is bad or if it contains excessive water, this is detected in advance and corrective measures can then be taken in time.

(b) A drift assists in the ventilation of tunnels.
(c) The quantity of explosives required is less.
(d) A side drift allows the use of timber to support the roof.

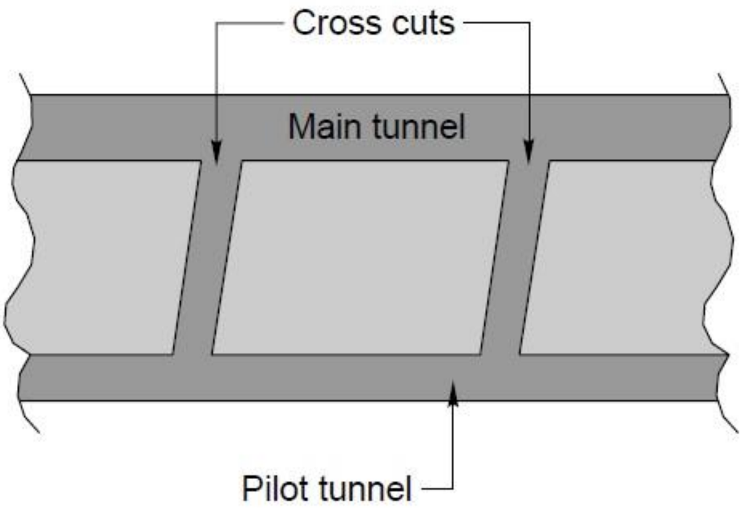
Disadvantages
(a) It is a time-consuming process, as the excavation of the main tunnel gets delayed till the drift is completed.
(b) The cost of drilling and removing the muck from the drift is high, as the work has to be done using manually operated power-driven equipment.



Drift method

Pilot tunnel method
This method normally involves the digging of two tunnels, namely, a pilot tunnel and a main tunnel. The cross section of the pilot tunnel usually measures about 2.4 m × 2.4 m. The pilot tunnel is driven parallel to the main tunnel and connected to the centre line of the main tunnel with cross cuts at many points. The main

tunnel is then excavated from a number of points. The pilot tunnel offers the following advantages.



Pilot tunnel

(a) It helps in removing the muck from the main tunnel quickly.
(b) It helps in providing proper ventilation and lighting in the main tunnel.
The method, however, requires the construction of an additional tunnel and therefore the time and cost of construction are higher as compared to the methods described before.

3.13.5.2 Tunnelling in Soft Ground or Soft Rock

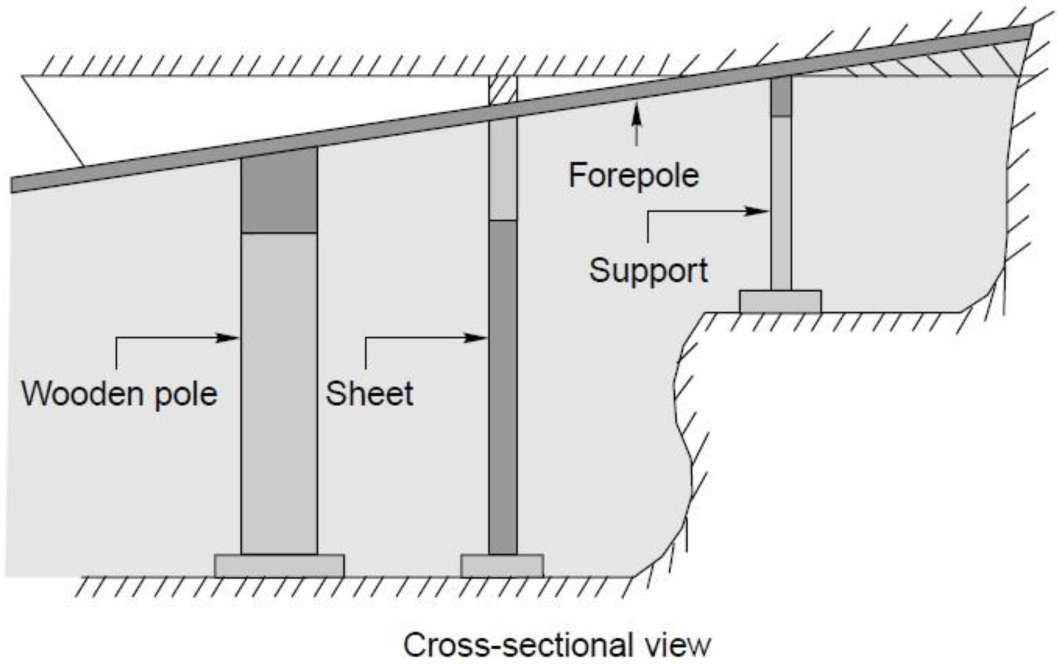
Tunnelling in soft ground or soft rock is a specialized job. It does not involve the use of explosives and the requisite excavation work is done using hard tools such as pickaxes and shovels. In recent times, compressed air has also been used for this purpose. During excavation, the rail requires support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

In the case of soft rock, the selection of the method of tunnelling depends upon the following important factors.
(a) Nature of ground
(b) Size of tunnel
(c) Equipment available
(d) Sequence of operations
Some of the important methods of tunnelling in soft rock are described in the

following sections.

Forepoling method

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

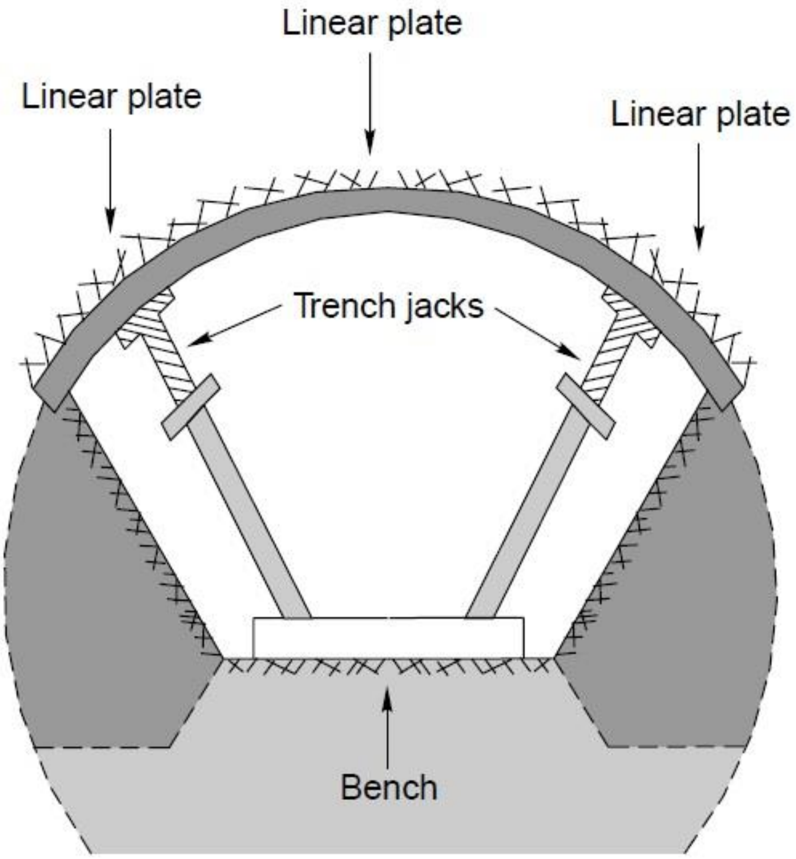


Forepoling method

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

Linear plate method

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

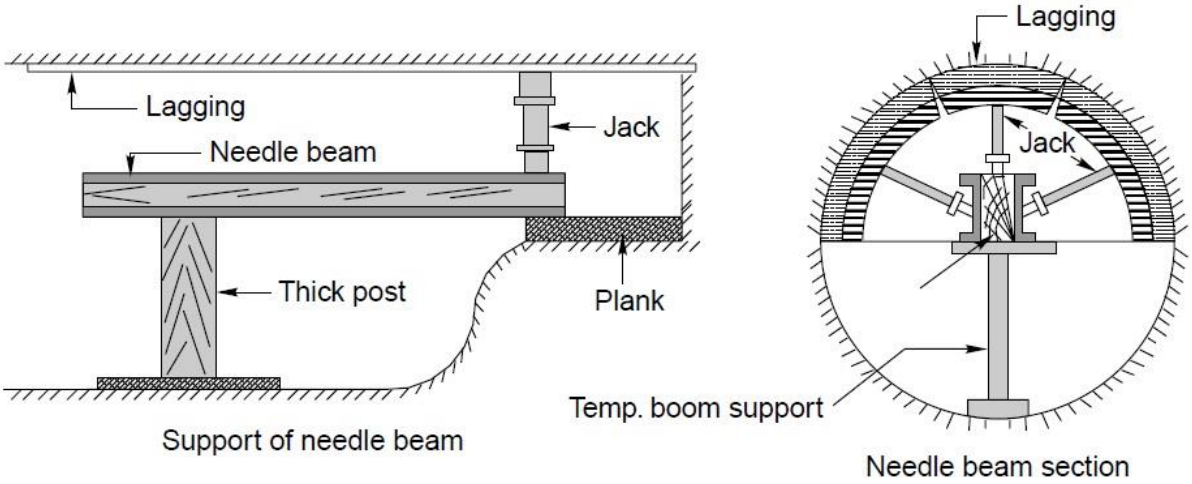


Linear plate method

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

Needle beam method

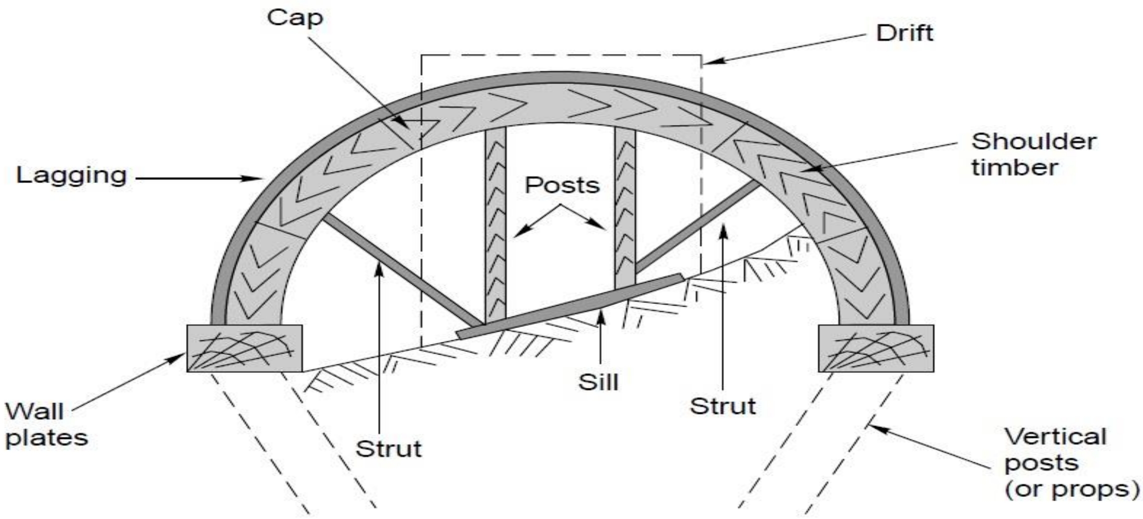
The needle beam method is adopted in terrains where the soil permits the roof of the tunnel section to stand without support for a few minutes. In this method, a small drift is prepared for inserting a needle beam consisting of two rail steel (RS) joists or I sections and is bolted together with a wooden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



Needle beam method

American method

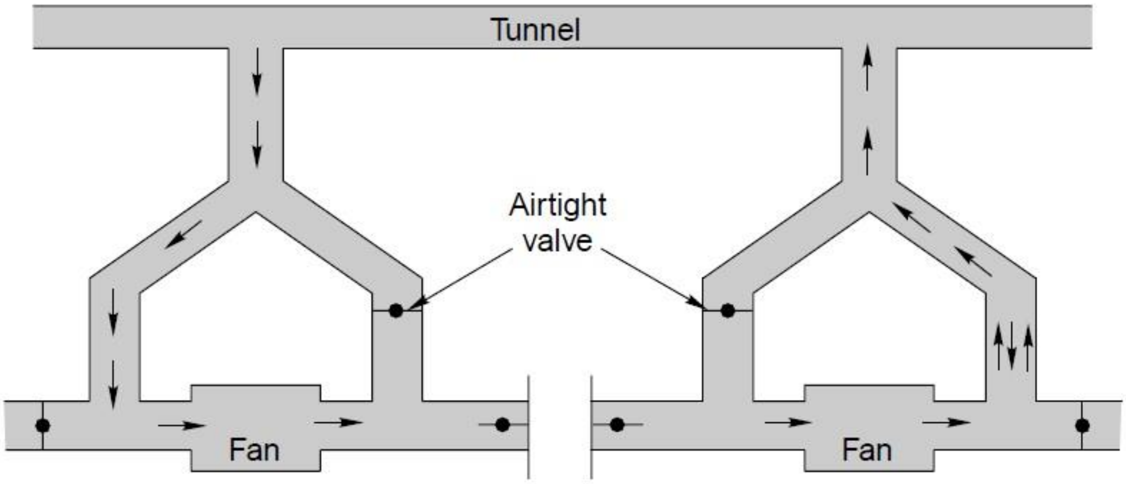
In this method, a drift is driven into the top of the tunnel. The drift is supported by laggings, caps, and two vertical posts. The sides of the drift are then widened and additional support is provided using timber planks and struts. The process of widening is continued till it reaches the springing level. Wall plates are fixed at the springing level, which in turn are supported by vertical posts. The vertical posts now occupy the entire roof level. The posts supporting the drift can then be removed and tunnelling work continued further in a similar manner.



American method

3.14 Ventilation of Tunnels

A tunnel should be properly ventilated during as well as after the construction for the reasons given below.
(a) To provide fresh air to the workers during construction.
(b) To remove the dust created by drilling, blasting, and other tunnelling operations.
(c) To remove dynamite fumes and other objectionable gases produced by the use of dynamites and explosives.
The methods listed below are normally adopted for the ventilation of a tunnel.



Ventilation of tunnels

Natural method of ventilation This is achieved by drilling a drift through the tunnel from portal to portal. In most cases natural ventilation is not sufficient and artificial ventilation is still required.

Mechanical ventilation by blow-in method

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

Mechanical ventilation by exhaust method

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

Combination of blow-in and blow-out methods

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

3.15 Lighting of Tunnels

It is very important to ensure that the tunnels are well lit so that the various activities and operations involved in tunnelling can be carried out effectively and safely. The common types of lighting equipment normally used in tunnels are electric lights, coal gas or acetylene gas lights, or lanterns. Electric lights are considered the best option, as these radiate bright light of the required intensity, are free from smoke, are easily manoeuvrable from the point of view of extension, etc.

Places where plenty of light should normally be provided are operation points, equipment stations, bottom of shafts, storage points, tempering stations, underground repair shops, etc.

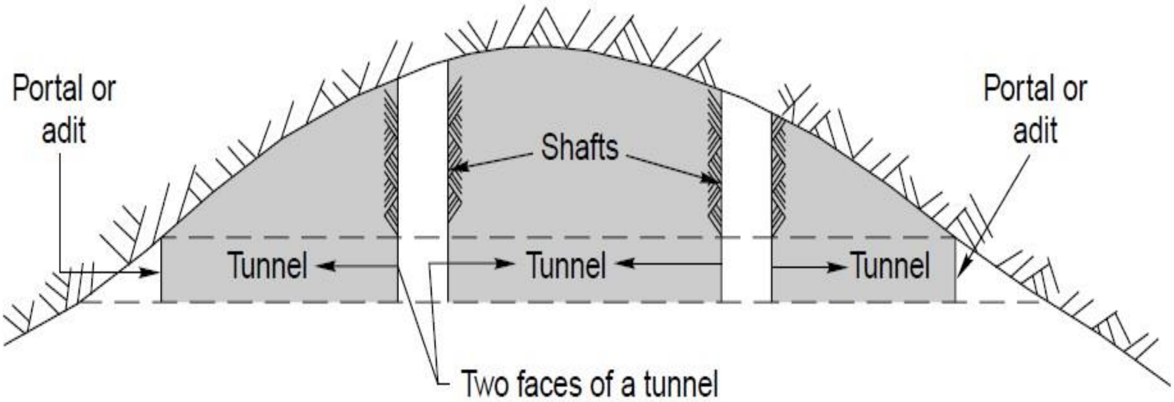
3.16 Drainage of Tunnels

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

After the construction is over, drainage ditches are provided along the length of the portion of the tunnel that slop from the portal towards the sump well and are used for pumping the water out.

3.17 Shaft of Tunnels

Shafts are vertical wells or passages constructed along the alignment of a tunnel at one or more points between the two entrances. A shaft is provided for the reasons listed below.



Tunnel shafts

Working shafts These are provided for the expeditious construction of tunnels by tackling the same at a number of points. These are generally vertical and of a minimum size of 3.7 m × 3.7 m or of a diameter of 4.30 m.

Ventilation purposes In order to ensure better ventilation, these shafts are generally inclined and have a girder size of about 1.2 m diameter.

3.18 Lining of Tunnels

Tunnels in loose rock and soft soils are liable to disintegrate and, therefore, a lining is provided to strengthen their sides and roofs so as to prevent them from collapsing. The objectives of a lining are as follows:

(a) Strengthening the sides and roofs to withstand pressure and prevent the tunnel from collapsing.

(b) Providing the correct shape and cross section to the tunnel.

(c) Checking the leakage of water from the sides and the top.

(d) Binding loose rock and providing stability to the tunnel.

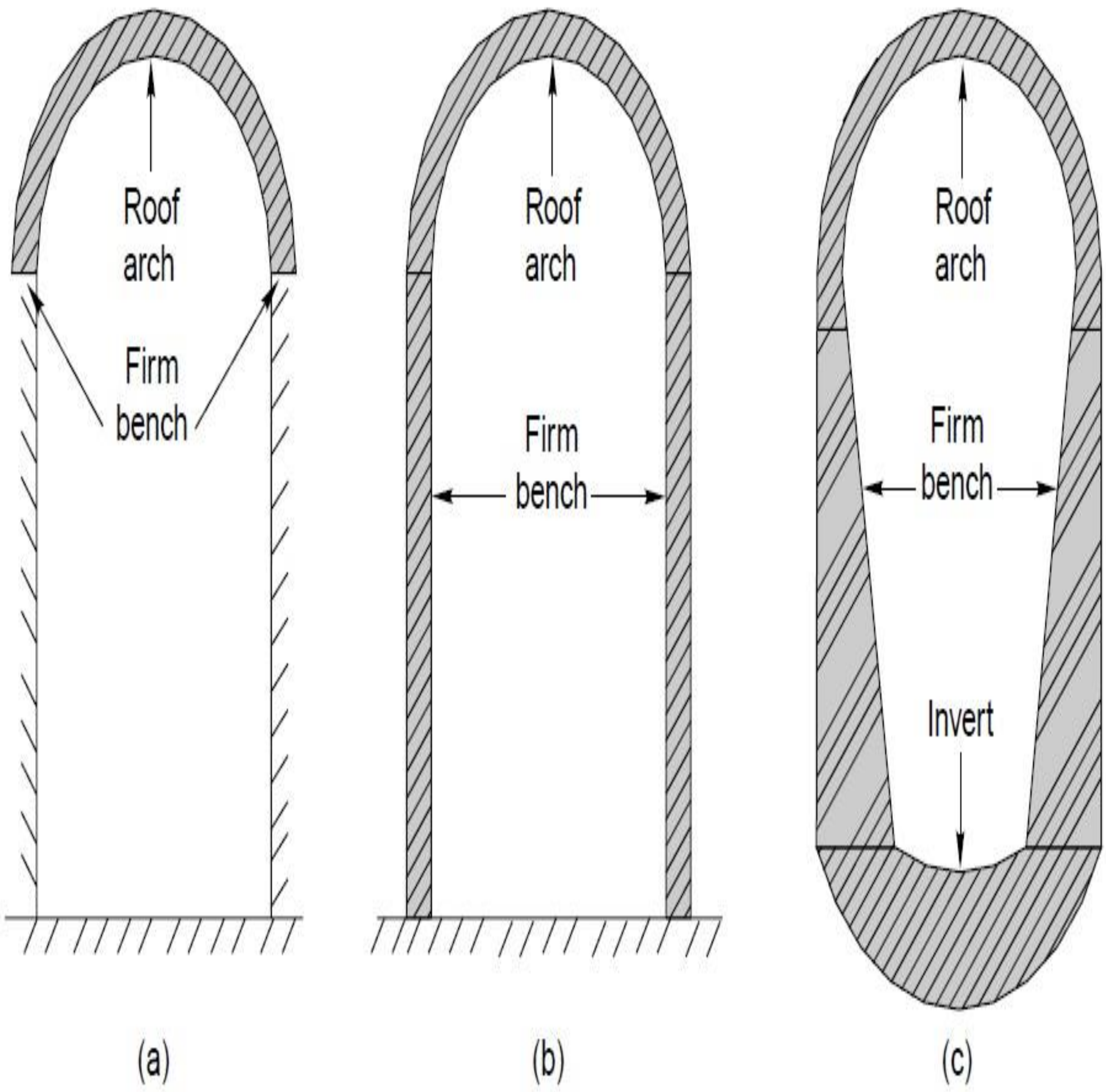
(e) Reducing the maintenance cost of the tunnel.

3.18.1 Sequence of Lining

The lining of a tunnel is done in the following steps.

1. In the first stage guniting is done to seal the water in rock tunnels.
2. Concrete lining is done either in one attempt as in the case of circular tunnels or by separately tackling the vest, the sidewall, and the arch. For small tunnels that measure 1.2 to 3.0 m in diameter, the concrete lining can be provided by the hand placing method. In the case of bigger tunnels, concrete pumps or pneumatic placers are used for placing the concrete.

3. The concrete is cured to its maximum strength. If the humidity inside the tunnel is not sufficient, curing can be done by spraying water through perforated pipes.
4. The different types of lining practices adopted by Indian Railways depending upon ground conditions are depicted.



Linings of tunnels

3.19 Safety in Tunnel Construction

Tunnelling is a difficult, hazardous, and time-consuming process and the whole operation has to be done systematically so that safety is ensured at all times. Normally accidents in a tunnel occur under the following circumstances.

(a) Falling rocks
(b) During the loading and hauling of muck
(c) Poor handling of explosives
(d) During shaft operations
(e) Cramped working space

The following tips are suggested for preventing accidents during tunnelling operations.

(a) Equipment and tools should be in good working condition.
(b) Regular and detailed inspections should be carried out during tunnelling operations.
(c) Visual inspections should be done to detect seams and planes of weakness so as to avoid the falling of rocks.
(d) There should be provision of sufficient support by ensuring that tunnelling is done properly in order to avoid the collapsing of the tunnel as well as falling rocks.
(e) There should be provision of good lighting and non-slippery walkways, which partially help in relieving the strain of a cramped working space.
(f) Provisions should be made for the removal of extra debris and refuge as well as for good drainage in order to avoid accidents. Efforts should also be made to provide good ventilation.
(g) Telephone facilities should be provided, particularly inside the shaft and at other places in the tunnel, to ensure smooth and accident-free operations.
(h) Firefighting equipment should be provided at all key points.
(i) Safety sign boards should be provided at all key locations.
(j) All workers should be medically fit to work inside the tunnel and they should be examined periodically. Doctors and first aid facilities should be available at the site.
(k) Wearing of helmets by all workers employed in a tunnel should be made mandatory.

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL
SONEPAT

E-NOTES

SUBJECT: TRANSPORT ENGINEERING 2 SUBJECT CODE: CE-310B

COURSE- BTECH BRANCH: CIVIL ENGINEERING

SEMESTER 6TH CHAPTER NAME: AIRWAYS UNIT 4

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

4.1 HISTORY & GROWTH OF AVIATION:

The history of aviation is indeed fascinating and makes a thrilling story of adventure and achievement. Though essentially a record of triumphs of men and machines, yet predominantly it is a saga of brave individuals, their courageous deeds, their unconquerable human spirit, their uncompromising determination and above all their selfless sacrifice for a passionate cause 'the love for flying'.

The early aviators and experimenters toiled hard and risked their lives to achieve the feat of flying, which they ultimately did accomplish. Their exploits were exciting and their discoveries are important. It behaves us today to remember, in thanks giving, the heroic deeds of the pioneers in flying and pay tribute to the sacrifices of earlier adventurers who made flight by man possible and progressively made it safe. In this regard, an endeavor has been made to recapitulate the story of aviation in a historical perspective, collating certain scarcely known facts and recently researched manuscripts.

A) The Human Ambition:

Man has always been cherishing the ambition to fly high and move freely in the air. Flights of the birds always fascinate him and stir his imagination. Being intrigued by this phenomenon of flying which he could not accomplish in his early years, he fancifully accorded his Gods the ability to exercise their will through the medium of the air. Greek god Hermes wore winged sandals. Cupid is believed to have wings, so was Mercury, the Divine Messenger. The legends of Daedalus and his son Icarus, who flew with wings (made of feathers fixed by wax held on to their arms), from the island of Crete, are well known.

B) The Early Attempts:

The annals record that an English monk and philosopher Roger Bacon (1214-1294) had designed a flying chariot. So had the Italian artist-scientist Leonard Da. Vinci (1452 - 1519), who also devised a mechanism to enable men to operate a pair of flapping wings by leg power. But this "Bird Machine" was never built.

C) Flight with Kites:

The kites (believed to have invented in China around 1000 B. C.) were an instrument of man's earliest success in making a heavier than air object fly in the air. It is on record that kites of such huge sizes had been developed which could lift a man and are known to have been used for military purposes as early as the seventeenth century by the Chinese and the Japanese. History reports that Greek General, Archvtas, in 40 BC, made several futile attempts to get airborne. One day, he stumbled upon a sharp incline and the kite broke his fall and saved him. A Korean General had also once suspended a lantern from a kite as a morale-boosting signal to his troops. And a Japanese bandit in an ingenious attempt, stole his way into a castle by suspending himself from a large kite, presumably to steal some fish.

D) Airlift Through Balloons:

Another line of research produced the balloon, which provided ascent gave freedom of Movement to fly but precious title control. A Jesuit priest named Francisco de Lana Terzi is believed to have produced the first known design for a lighter-than-aircraft in 1670. He had toyed with the idea of a "flying boat" with four hollow metallic spheres that would float in the air but it failed.

It was only in the later half of the eighteenth century that enough knowledge had been gained and gathered in the Europe to travel through the medium of air by hot air-balloon.

E) Airships and Dirigibles:

The next stage of development was the construction of airships called "dirigibles or blimps" which remained aloft by buoyancy alone. These were based on the Archimedean principle and were actually an adaptation of the balloons. Meusnier, a French army officer conceived the design of its cigar-like shape, in 1784, but for the purpose of propulsion the steam engines then existing were too heavy. For its success, this design had to wait till the invention of petrol driven engine in 1890. As yet, these had neither propelling force nor steering systems.

4.2 DEVELOPMENT OF CIVIL AVIATION INDUSTRY IN INDIA:

A perusal of the changing air-route map in India during the period 1932 till 1953 reveals the historical development in air transport business in India.

A) Pre-Nationalisation Development Phase:

The air transport service in India grew steadily during the pre-nationalisation period between 1932 and 1939, until Second World War temporarily disrupted these services. War however brought boom into Civil Aviation in India with post war inventory of surplus aircraft, network of aerodromes and ground based meteorological, navigation and communication infrastructure. As a consequence early enthusiasm led to mushrooming of a number of domestic airlines without due consideration of minimum need for planning / organisation and back-up overhaul/ repair infrastructures and above all financial resources.

The development of post-war Civil Aviation scenario in India was perceived and analysed by the then Director General of Civil Aviation, known as 'Tymm's plan' who recommended:

i) Licensing of air transport services by an Autonomous Licensing Board.

ii) Scheduled air service to be entrusted only to the few competent private airline Companies, not exceeding four, each assigned with adequate route mileage and scope for development, so as to ensure efficient and economic use of aircraft fleet, ground equipment and manpower.

iii) Airlines to operate on commercial basis in order to meet certain cost and or revenue targets, to be viable.

The interim government formed prior to Independence in September 1946, however, ignored such economic realities of the nascent airline industry to enable its healthy and orderly growth.

Further, ministerial interference's and pressures spoilt the basic character of an 'Autonomous Licensing Body' which subsequently granted provisional license to 11 operators for 51 routes, form among hundred applicants for 96 routes covering whole of India.

B) Post-Nationalisation Scenario:

As a start with nationalisation began an orderly take off of Indian aviation in early 50's. Indian Airlines Corporation successfully overcame the complexity of integration of assets and business culture of 8 different domestic airlines. These airlines were operating scheduled air services from spread-out bases and had large manpower with varying work culture and emoluments. It is to the credit of Indian Airlines management that this task was accomplished admirably well in a short time. Indian Airlines Corporation was transformed into an efficient and homogeneous organisation, which consolidated its ground support services.
Carried out standardisation of operational set-up fleet and expanded service network by nationalising its routes.
During 1954-55 Indian Airlines Corporation carried around 4,80,000 passengers. Despite heavy burdens of wages of excess manpower and obsoletes inventory of equipment/capital assets. Indian Airlines Corporation managed to contain its operational costs (including 35% costs towards fuel taxation) gradually reducing operating losses and even made marginal profits in 1959-60. To cater for growth in traffic, Indian Airlines Corporation introduced modern medium size jet service on trunk routes and
selectively also flew International services. The historical traffic analysis shows by and large steady and long-term average growth at times in access of over 10 % per year. Apart from being capacity dependent the traffic growth has been strongly influenced by national income of the country in Industrial business growth and tourist promotion. For the first time in 1987-88 Indian Airlines crossed 10-million passenger mark.

C) Initiation of Liberalisation:

In July 1991, the Central Government of India initiated economic reforms, when faced with compulsion of balance of payment and dwindling forex reserves. With the liberalisation, the economic parameters strengthened, and all round progress noticed in industrial and national growth. The liberalisation process in Civil Aviation, commenced early w.e.f. 1990-91, by allowing International freighters to operate air cargo services from to India without reference to Director General of Civil Aviation. This helped International trade in particular export, with upliftment of air cargo piled up at the airports. The shippers were thus benefited with timely availability of capacity, range of service and wider choice of rates hence the term 'Open Sky' for the air cargo was coined.

4.3 STRUCTURE OF INDIAN CIVIL AVIATION:

The Ministry of Civil Aviation of the Government of India is the apex body in the regulatory/ (organisational) structure of Civil Aviation in India. The ministry of Civil Aviation is responsible for the formulation of national policies and program's for development and regulation of Civil Aviation and for devising and implementing schemes for orderly growth and expansion of civil air transport. Its functions also extend to overseeing the provisions of airport facilities, air traffic services and carriage of passengers, goods, and services. Within its administrative preview lie three distinct functional entities namely regulatory cum development, operational, and infrastructural.

A) Regulatory Functions:

The Directorate General of Civil Aviation and the Bureau of Civil Aviation security performs the regulatory functions, which is responsible for ensuring adequate security arrangements at the airports in all its aspects.

B) Operational Functions:

The operational functions are performed by Air India ltd., and other scheduled non-scheduled airline operators. Air India ltd. (Al) provides International air services to/from India, Indian Airlines ltd. and other scheduled non-scheduled operators are responsible for providing domestic air service in the country. Indian Airlines ltd. Provides International Air service to some of the neighbouring countries Pawan Hans ltd. Provides helicopter support service primarily to the petroleum sector.

C) Infrastructural Functions:

The Airport Authority of India provides the infrastructural facilities, which is responsible for the management of 92 airports, including the five International airports Delhi, Mumbai, Calcutta, Chennai, and Thiruvananthapuram, and 28 civil enclaves at the defence airports. The airport authority of India was formed on 1st April 1995 by the merger of International airport authority of India.

4.4 Airport Planning

Airport planning requires more intensive study an9 fore thought as compared to planning of other modes of transport.

This is because aviation is the most dynamic industry and its forecast is quite complex.

Unlike rail, road and water transportation, air transportation has yet not reached a steady state in design. it is very difficult to predict for the airport.

4.5 Airport Master Plan

Airport master plan refers the planner's idealized concept of the form and structure of the ultimate development of the airport.

Master planning can apply to the construction of new airports as well as to significant expansion of existing facilities.

The **objectives** of the master plan according to FAA are:

1. To provide an effective graphical presentation of the ultimate development of the airport are of the anticipated land uses adjacent to the airport.

2. To establish a schedule of priorities and phasing for the various improvements proposed in the plan.

3. To present the pertinent back-up information and data which were essential to the development of the master plan.

4. To describe the various concepts and alternatives which were considered in the establishment of the proposed plan.

4.6 Planning of a new airport:

Step 1

_ The most important item in a airport planning is to estimate the future volume of air traffic.

_ Peak hoar volumes of passenger cargo and mail are required for proper allocation of space in the terminal building and for determining the size of the building.

Peak hour aircraft movements assist in the design of runways, taxi and loading Aprons

Following data is collected for the traffic forecast

_ Area to be served

_ Origin and destination of the residents and non residents of the area

_ Population growth in the area
_ Economic character of the area
_ Income level per capita
_ Types of business activities and the labour employed
_ Trends in existing local traffic
_ Trends in national air traffic volume
_ Population, growth and economic standards of adjacent areas

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

Step 2

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

Following points are considered in this respect
_ Suitability of approaches for the type of airports.
_ Capacity of runways and taxiways to handle the peak hour traffic for airport capacity
_ Adequacy of terminal building of handling 4 passengers and cargo.
_ Adequacy of aprons and servicing facilities.

Step 3

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

The improvement can be done in the following ways
_ Runway extensions, new or parallel runway' and high speed exit taxiways.
_ Rearranging or increasing the size of terminal building and/or loading apron.
_ Improving the traffic control devices

Step 4

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

4.7 AIRPORT SITE SELECTION

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

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

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

Above factors are briefly discussed as follows

Regional Plan

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

Airport Use

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

Proximity to Other Airports

_ The site should be selected at a considerable distance from the existing airports so that the aircraft landing in one airport does not interfere with the movement of aircraft at other airport.

_ The required separation between the airports mainly depends upon the volume of air traffic, the type of aircraft and the air traffic control, i.e. whether the airports are equipped with instrumental landing facilities or not.
The following minimum spacing have been suggested as a guide for planning
_ For airports serving small general aviation aircrafts
_ under VFR conditions 3 2 km (2 miles)
_ For airports serving bigger aircrafts, say two piston engine, under VFR conditions 64 km (4 miles)
_ For airports operating piston engine aircrafts under IFR conditions — 25.6 km (16 miles)
_ For aircrafts operating jet engine aircrafts under IFR conditions — 160 km (100 miles)

Ground Accessibility

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

Topography

_ This includes natural features like ground contours, trees; streams etc.
_ A raised ground e.g. a bill top, is usually considered to be an ideal site for an airport.
The reasons are:
• Less obstruction in approach zones and turning zones
• Natural drainage, low land may result in flooding
• More uniform wind
• Better visibility due to less fog

Obstructions
_ When aircraft is landing or taking off, it loses or gains altitude very slowly as compared to the forward speed.

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

Visibility

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

Noise Nuisance

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

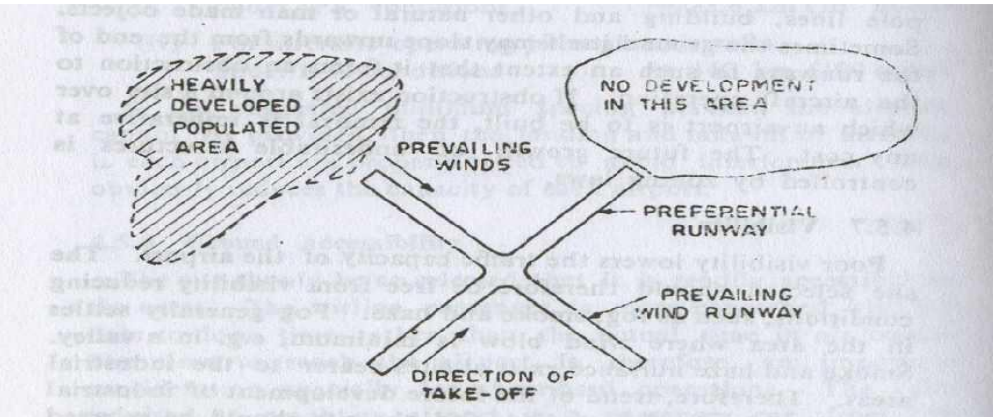


Figure 4.1 Area Recommended for Non-Residential Development

4.8 SURVEYS FOR SITE SELECTION

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

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

Topographical survey
_ To prepare contour map showing other natural features such as trees, streams etc.
_ To prepare a map showing such constructed objects aspole lines, building, roads etc.
These maps will be helpful in the jobs of clearing, grading and drainage.

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

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

Material survey

_ To ascertain the availability of suitable construction materials at a reasonable cost and the mode of transportation of these materials to the site. ground contours and the cross-sections and longitudinal profiles

4.9 ZONING LAWS

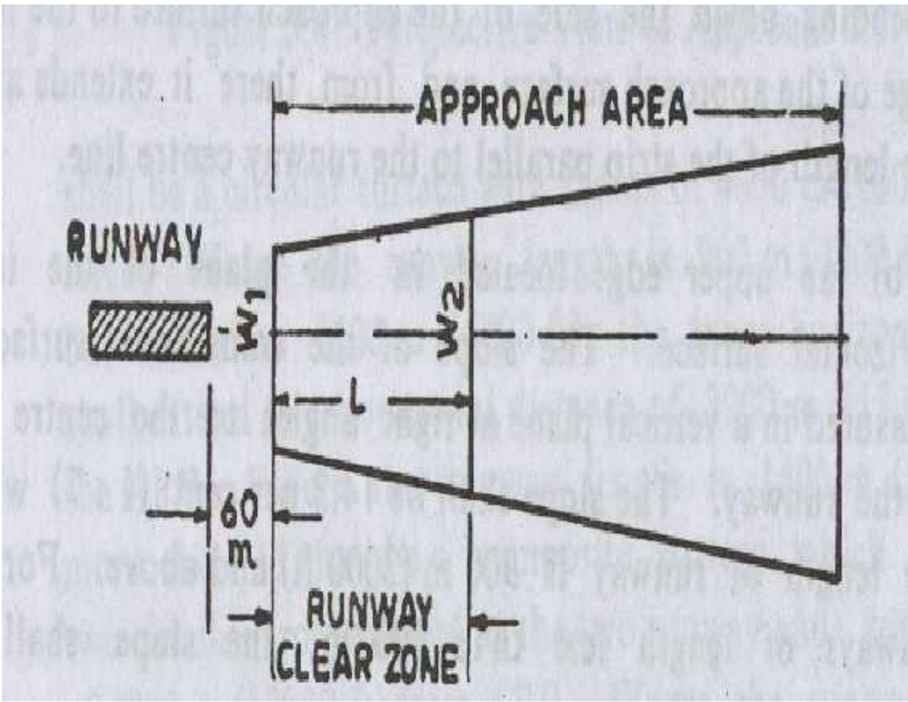
_ The permissible height of structures depends upon the airport and the aircraft types which would use the airport.
_ The use of land for manufacture of certain items which may result in smoke nuisance, foul odour etc. is also controlled by the zoning laws; It should, however, be con that all zoning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

4.9.1 APPROACH ZONE

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

4.9.2 Clear Zone

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



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

4.10 RUNWAY DESIGN

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

4.10.1 Wind Rose

_ The wind data, i.e., direction, duration and intensity are graphically represented by a diagram called wind rose.
_ The wind data should usually bi collected for a period of at least 5 years and preferably of two years, so as to obtain in average data with sufficient accuracy.
_ As far as possible, these observations should be taken at or near ‘site selected, since the wind conditions may vary considerably with location particularly in hilly regions.

Wind rose diagrams can be plotted in two types as follows:
Type I Showing direction and duration of wind
Type II: Showing direction, duration and intensity of wind

Type I Wind Rose
_ This type of wind rose is illustrated in Figure
_ The radial lines indicate the wind direction and each circle represents the duration of wind.
_ It is observed that the total percentage of time in a year during which the wind blows from north direction is 10.3 percent.

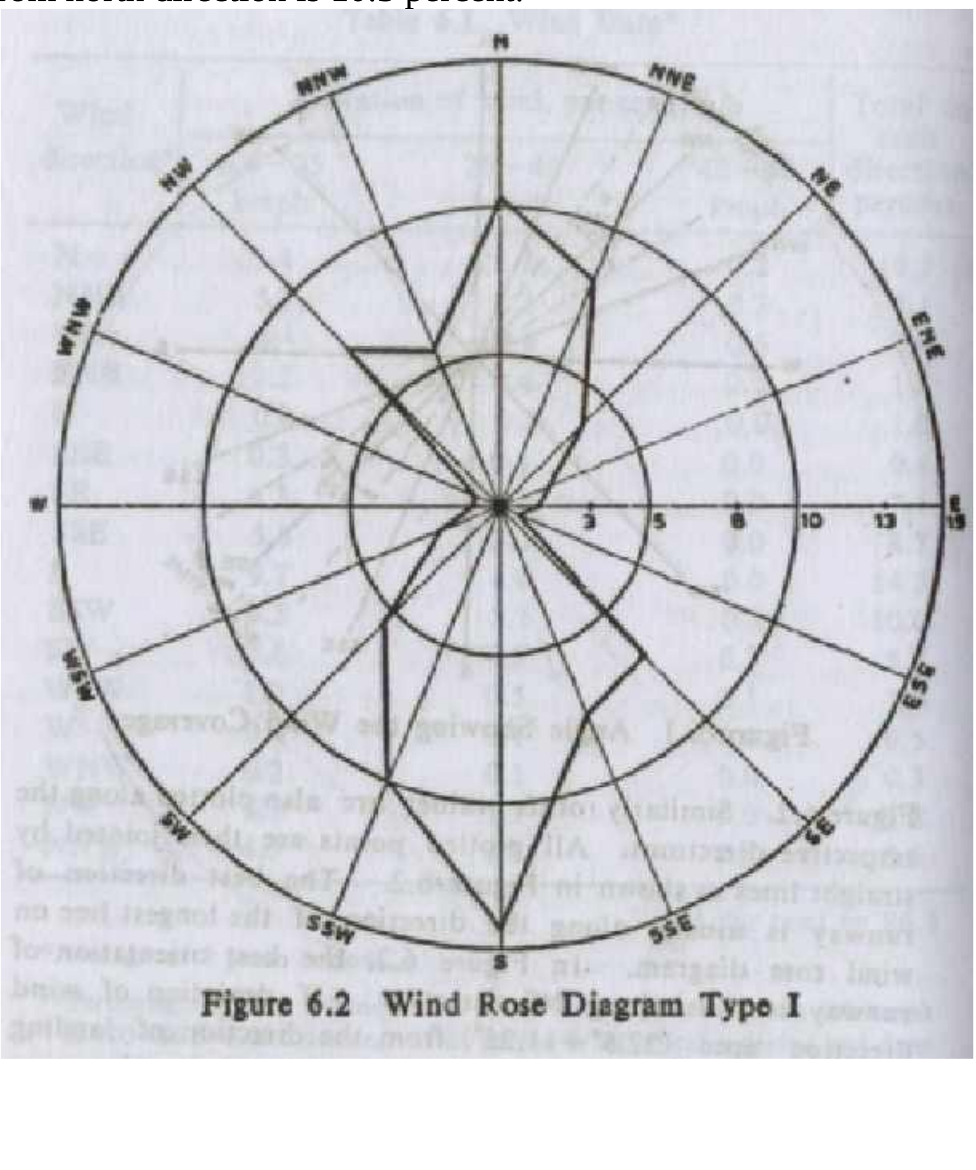


Figure 6.2 Wind Rose Diagram Type I

_ Similarly other values are also plotted along the respective directions,
_ All plotted points are then jointed by straight lines as shown in Figure
_ The best direction of runway is usually along the direction of the longest line on wind rose diagram.
_ In Figure the best orientation of runway is thus along NS direction.
_ If deviation of wind direction up to (22.5'+ I 1.25') from the direction of landing and take-off is permissible, the percentage of time in a year during which the runway can safely be used for landing and take-off, will be obtained by summing the percentages of time along NNW. N. NNE, SSE. S and SSW directions.

_ This comes to 57.0 per cent. Calm period, i.e., the percentage of time during which wind intensity is less than 6.4 kmph is also added to the above period.
_ The total percentage of the time therefore comes to 57.0 + 13.5 705. This type of wind rose does not account for the effect of cross wind component.

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

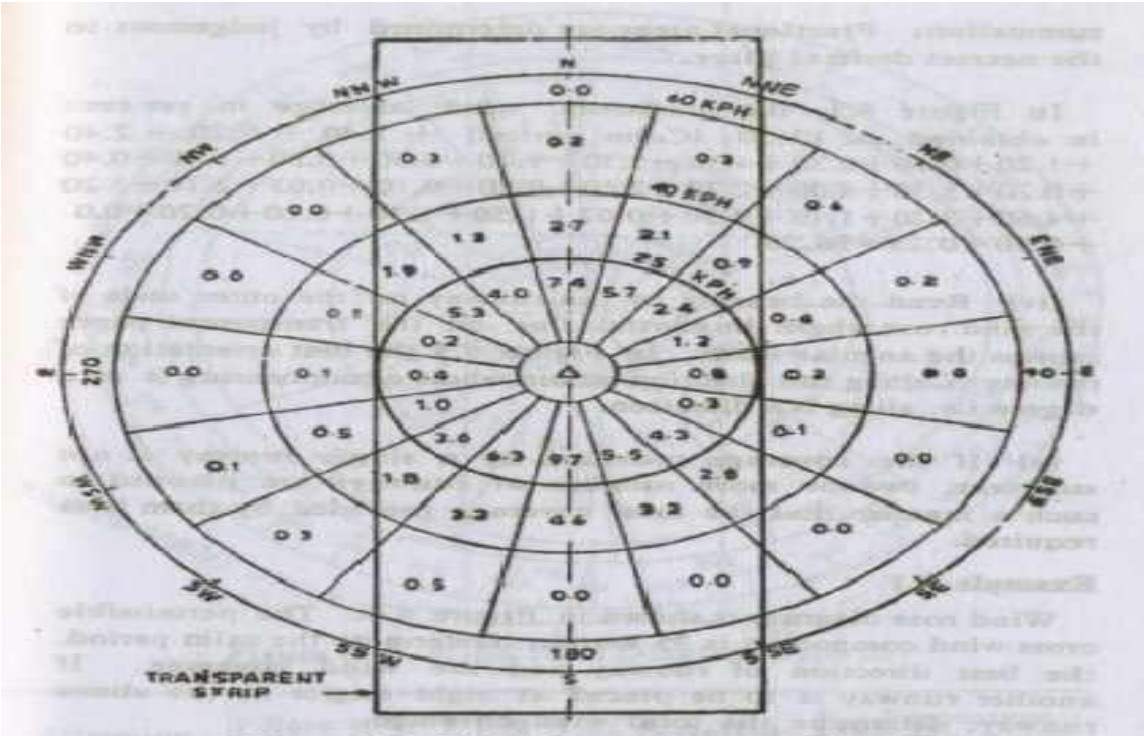


Figure 6.3 Wind Rose Diagram. Type II

_ With the centre of wind rose, rotate the tracing paper and place it in such a position that the sum of all the values indicating the duration of wind, within the two outer parallel lines, is the maximum.
_ The runway should be thus oriented along the direction indicated by the central line.

_ The wind coverage can be calculated by summing up all the percentages shown in segment.
_ The percentage value is assumed to be equally distributed over the entire area of the segment.
_ When of the outer parallel lines of the transparent strip crosses a segment, a fractional part of the percentage appearing in that segment within the outside lines is also counted in the summation.
_ Read the bearing of the runway on the outer scale of wind rose where the central line on the transparent paper crosses the angular scale.
_ In Figure the best orientation of runway is along the direction whose whole circle bearing is zero degree i.e. along NS direction.
_ If the coverage provided by a single runway is not sufficient, two or more number of runways are planned in such a manner that the total coverage provided by them is as required.

Correction for Gradient
_ Steeper gradient results in greater consumption of energy and as such longer

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

4.11 RUNWAY GEOMETRIC DESIGN

4.11.1 Runway Length

_ The basic runway lengths as recommended by ICAO for different types of airports.
_ To obtain the actual length of runway, corrections for elevation, temperature and gradient are applied to the basic runway length

4.11.2 Runway Width

_ ICAO recommends the pavement width varying from 45 m (150 ft to 18 m (60 ft) for different types of airports.
_ The typical transverse distribution of traffic on a runway is shown in Figure
_ The figure indicates that the aircraft traffic is more concentrated in the central 24 m (80 ft) width of the runway pavement.
_ Another consideration in determining the runway width is that the outermost machine of large jet aircraft using the airport should not extend off the pavement to the shoulders.
_ This is because the shoulder is usually of loose soil or established soil etc. which is likely to get into the engine and damage it;

_ The outer engines of a large jet transport are about 13.5 m (45 feet) from the longitudinal axis of the aircraft.
_ As such a pavement width of 45 m t provide adequate protection to the engine from the shoulder material during normal operations.

4.11.3 TERMINAL AREA

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

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

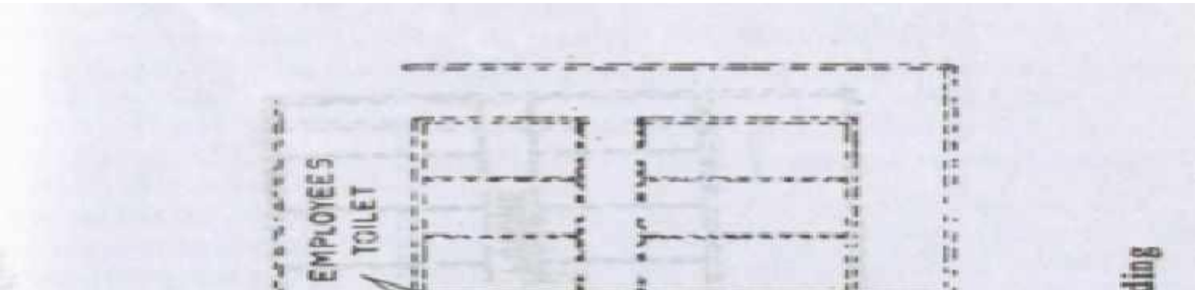
4.11.4 BUILDING AND BUILDING AREA

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

4.11.5 Building Functions

The various facilities provided in the airport buildings are as follows
_ Passengers bud baggage handling counters for booking
_ Baggage claim section
_ Enquiry counter
_ Space for handling and processing mail, express and light cargo
_ Public telephone booth

_ Waiting hall for passengers and visitors
_ Toilet facilities
_ Restaurants and bars
_ First aid room
_ General store and gift shops
_ Space for magazines, news display etc.
_ Office space for airport staff
_ Weather bureau
_ Post office and banking facilities
_ Custom control
_ Passport and health controls
_ Control tower



4.12 Site Location

_ The correct placement of the terminal building with respect. to the runways and loading aprons result in a more rational approach for the airport development.
_ As the planning of runway proceeds, the requirements of building sites are also kept constantly in view.
_ The location of the runways are finalized with proper designation of adequate building area.
_ The suitability of an area, as a site for terminal building development, is evolved in accordance with the following requirements

• Sufficient area for the first stage of building development with possibility of future expansion
• Sufficient area for roadways
• Adequate area for car parking
• Layout of above items providing functional relationship with each other
• Convenient access of the main highway
• Central location with respect to runway

• Proximity and easy installation of utilities, e.g.telephone electricity, water, sewage, etc.
• papers, advertisement
Planning Considerations
_ Two concepts are there for planning of the terminal buildings for a commercial airport, viz., centralization and decentralization.
_ In the centralized plan, all passengers, baggage and cargo are funneled through a central building and are then dispersed to the respective aircraft positions.
_ In the decentralised plan, the passengers and baggage arrive at a point near the departing plane.
_ All airline functions are carried out adjacent to the departing plane.
_ The choice of a particular type of plan is governed by the space needed for parking of the aircrafts.
_ When the aircraft parking area is located at an overall walking distance exceeding 180 m. a change from the centralized system becomes necessary.
_ Further, when the number of gate positions (loading area required for each aircraft) required for the individual airliner at one airport exceeds the decentralized plan also becomes operationally uneconomical.
_ At this situation, another shift towards the ceatralization of each individual airline Operation becomes essential.
_ This results in a series of centralized airline spaces, arranged in a decentralized pattern.
_ The concept of an airport from the centralization to decentralization and finally decentralization to centralization.
_ In the past, passenger terminal facilities at almost all airport in the world have been in the form of a single central terminal building containing all the required facilities and amenities.

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

exclusively to them.
_ It may be located close and connected with the operating units and may serve a single Unit, or a group of them.
_ The operating or handling units Would be purely functional with only such essential amenities as book stall, money changer, flight insurance booths and toilets.
_ This concept of a separate building for amenities would lend itself conveniently to the separation of domestic and international.
_ The principle of a separate structure connected with the handling Units should be applied wherever possible, leaving space for additional units to meet later expansion needs.
_ The unit terminal principle fits in exceptionally well with the modern concept of parallel runway patterns at large airports.
_ Finally, the unit terminal concept automatically minimizes initial capital expenditure, while ensuring that addition can easily be made later, without rendering any of the previous expenditure as waste.
_ The International Airport Committee, has recommended that full consideration be given to the adoption of the unit terminal principle for the new terminal facilities to be constructed at the international airports in India.

4.13 Vehicular Circulation and Parking Area

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

airport vehicular circulation and parking system.

4.13.1 Nose-in and angled nose-in

The **advantages** of this configuration are:
_ Less noise while taxing in because no turning is required.
_ Hot blast is not directed towards the terminal building.
_ The aircraft forward door is close to the terminal building.
The **disadvantages** are:
_ The aircraft rear loading door is far away from terminal building

4.13.2 Nose-in and angled nose-out

The **advantages** of this configuration are as follows:
_ Less power is required while manufacturing the aircraft out of its gate position.
_ The rear loading door is close to the terminal building.
_ Overall apron area required is generally small.
The main **disadvantage** is:
_ The hot blast is directed towards the terminal building.

4.13.3 Parallel System

The main advantage of this system is:
_ Both, the front and the rear doors are adjacent to the terminal building.
_ But this type of. parking configuration requires more space.
_ Further, the noise and the hot blast are directed towards the adjacent gale position.
_ Thus, it is evident that no single parking configuration can be considered as an ideal one.
Aircrafts can be grouped adjacent to **terminal building** in various ways:

Frontal system
Open apron .system
Finger system
Satellite system
These parking systems are illustrated in Figure and are discussed below

Frontal system

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

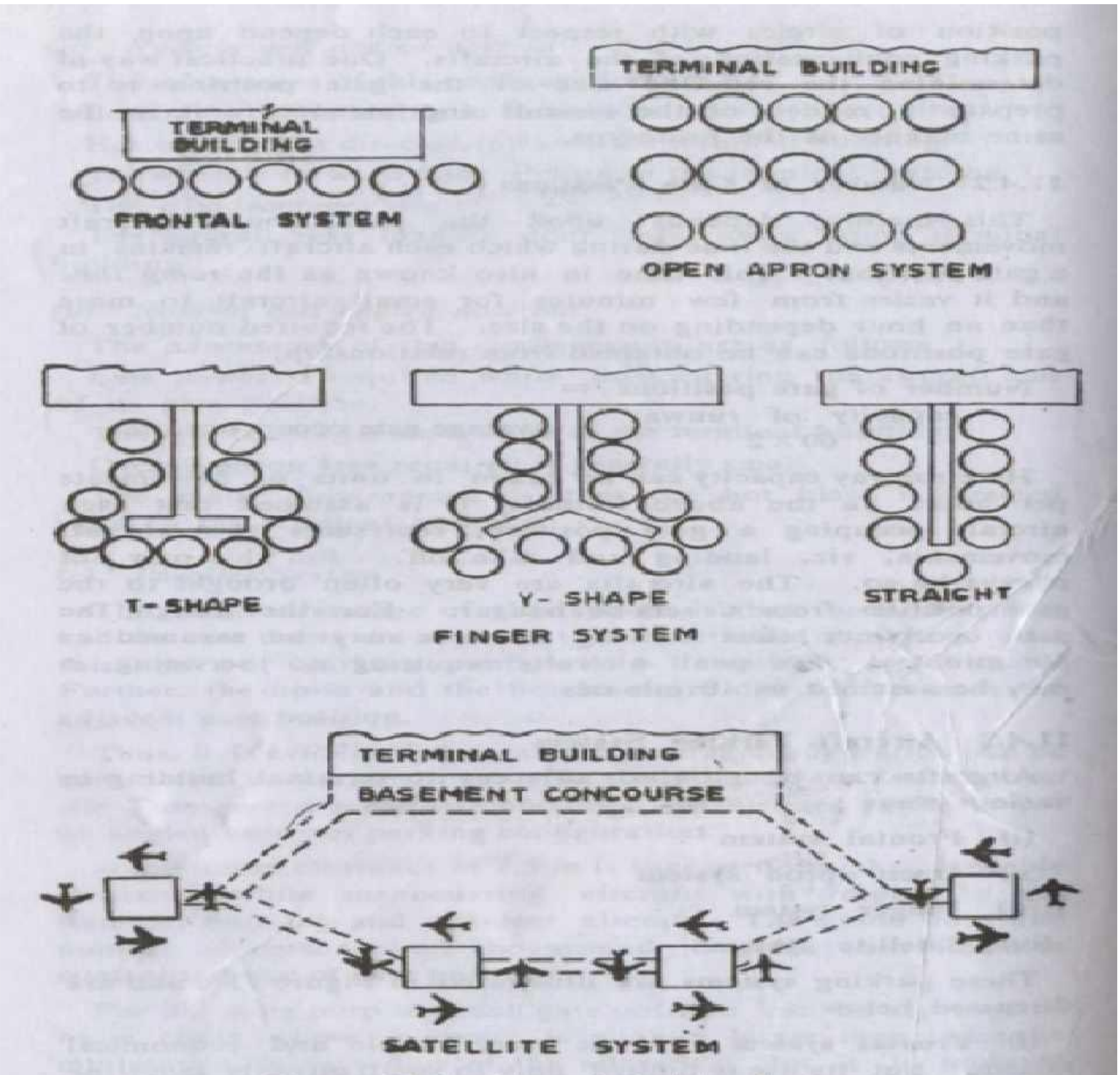


Figure 11.6 Aircraft Parking System

Open apron system

_ In this system the aircrafts are parked in rows.
_ If the number of aircrafts is too large, passengers may have to walk long distances or reach the aircrafts parked in the outermost row.
_ They are thus exposed to weather, noise and hot blast of the jet aircrafts.
_ To protect the passengers front such nuisance, some sort of closed vehicle conveyance for the passengers may be essential.

Finger system

_ Processing of passengers and their baggage is mainly done within the terminal building.
_ But the facilities for passengers, for entering and leaving the aircraft, often require extensions of the terminal building.

_ Such extension is known as pier finger.
_ A typical arrangement is shown in Figure
_ The pier finger can be fenced open walkway or a closed structure, single or multistorey.
_ It can be a straight, 1-shaped or Y-shaped.

Its main **advantages** are

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

Satellite system

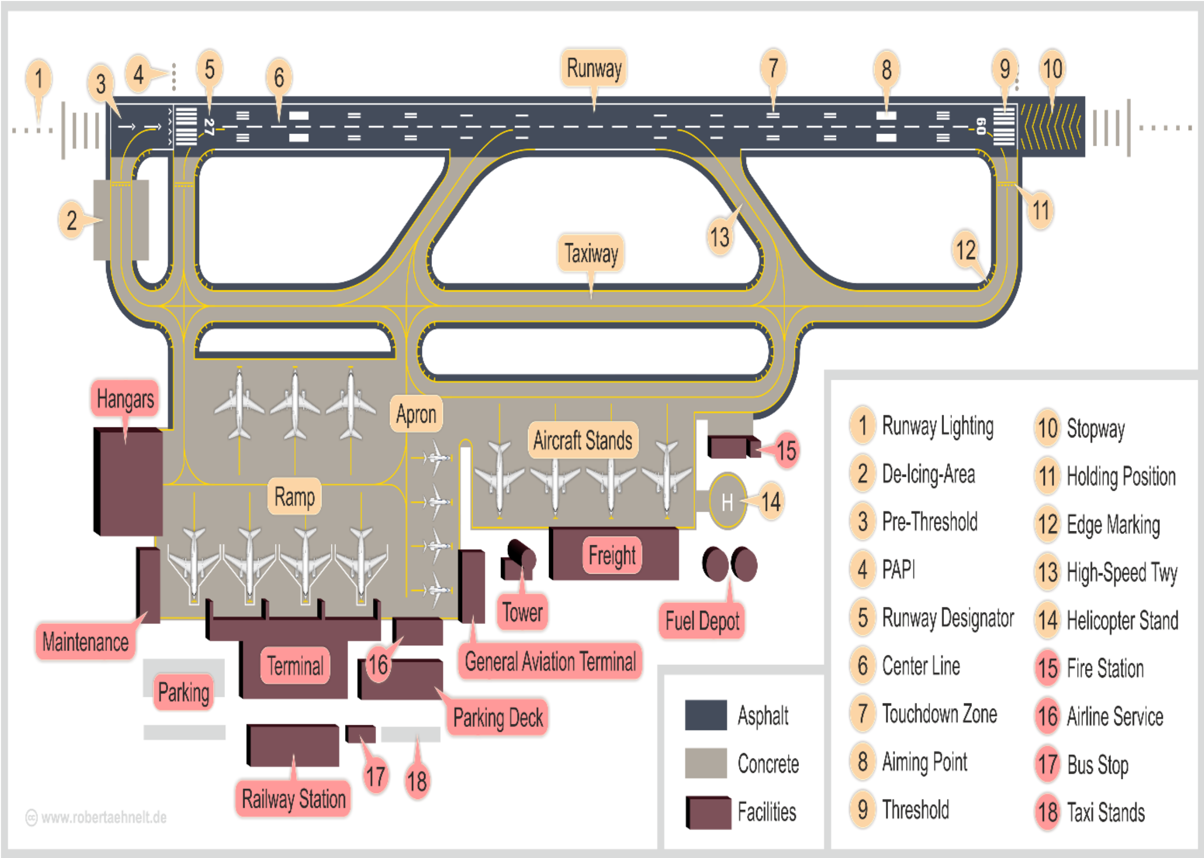
_ Satellites are small buildings located on the apron.
_ Aircrafts are parked around the satellite buildings which are connected to the main terminal building by underground tunnel.

_ This system is in use at the International airport of Los Angeles.
_ It is **advantageous**, compared to the pier finger system only when the connections to satellite buildings are through the tunnels.
_ In such an arrangement, the aircrafts are parked near the satellite as shown in Figure
_ Less turning is required to maneuver the aircraft in and out of the gate position.

The **disadvantages** of this system are
_ Large construct cost.
_ Passengers have to change the levels several times as they leave the terminal building for boarding the aircraft.

4.14 TYPICAL AIRPORT LAYOUTS

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



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

A good airfield layout should possess the following **Characteristics**
_ Landing, taxiing and taking off a independent operations without interference.
_ Shortest taxiway distances from loading apron to runway end.
_ Safe runway length
_ Safe approaches
_ Excellent control tower visibility
_ Adequate loading apron space
_ Sufficient terminal building facilities
_ Sufficient land area to permit subsequent expansion

_ Lowest possible cost of construction.

4.15 Components of Airport

Therefore, 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***.

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 upo9n 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***.

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

1. Runways
2. Taxiways
3. Apron
4. Terminal building
5. Control tower
6. Hanger
7. Parking

1. 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 take-off.

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%.

There are different runway patterns are available and they are

- Single runway
- Two runways
- Hexagonal runway
- 45-degree runway
- 60-degree runway
- 60-degree parallel runway

Single Runway

Single runway is the most common form. It is enough for light traffic airports or for occasional usages. This runway is laid in the direction of wind in that particular area.

Two Runway

Two runway contains two runway which are laid in different directions by considering cross winds or wind conditions in that particular area. The runways may be laid in the form of L shape or T shape or X shape.

Hexagonal Runway

This is the modern pattern of system of runway laying. In which the takeoff and landing movements of aircrafts can be permitted at any given time without any interference. This is most suitable for heavy traffic airports or busiest airports.

45 Degree Runway

45 degree run way is opted when the wind coverage for same airfield capacity is greater. This is also termed as four-way runway.

60 Degree Runway

When the wind in that area is prevailing in many directions, so, it is difficult to decide the direction in which runway is to be laid. In that case, 60-degree runway is opted which looks like triangular arrangement of runways.

60 Degree Parallel Runway

It is the extension of 60-degree runway, which is opted when the wind coverage is greater in other two directions then it is obvious that the third runway is to be chosen. But if the air traffic is more, then it is difficult to control the operations. Hence, another runway is required parallel to the using one. For that purpose, 60-degree parallel runway is suitable.

2. 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 taxying towards loading apron and the taxiing aircraft running towards the runway. The intersection of runway and taxiway should be given proper attention because during turning operation, this part comes under intense loading. If it is weaker 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.

- Terminal building:
- Mainly used for passengers, airline and administration facilities.
- Offers the enplaning passengers a convenient and direct access from vehicle parking area to booking room, waiting room & finally to apron.
- Deplaning passengers are provided a direct route from aircrafts to baggage claim counter and then to vehicle platform.

Terminal Area. A general term used to describe airspace in which approach control service or airport traffic control service is provided.

3. Apron

Apron is a place which is used as parking place for aircrafts. It is also used for loading and unloading of aircrafts. Apron is generally paved and is located in front of terminal building or adjacent to hangers. The size of area to be allotted for apron and design of apron is generally governed by the number of aircrafts expected in the airport. The aircraft characteristics also considered while design. Proper drainage facilities should be provided with suitable slope of pavement.

4. Terminal Building

Terminal building is a place where airport administration facilities takes place. In this building, pre-journey and post journey checking’s of passengers takes place. Lounges, cafes etc. are provided for the passengers. Passengers can directly enter the plane from terminal buildings through sky bridge, walkways etc.

5. Control Tower

The control tower is a place where aircrafts under a particular zone is controlled whether they are in land or in air. The observation is done by the controller through radars and information is carried through radio. The controller from the control tower observes all the aircrafts with in that zone and informs pilots about their airport traffic, landing routes, visibility, wind speeds, runway details, etc. based on which the pilot decides and attempts safe landing. So, control tower is like nerve system of an airport.

6. Hanger

Hanger is a place where repairing and servicing of aircrafts is done. Taxiway connects the hanger with runway so, when a repair needed for an aircraft it can be moved to hanger easily. It is constructed in the form of large shed using steel trusses and frames. Large area should be provided for Hanger for comfortable movement of aircrafts.

7. Parking

This is a place provided for parking the vehicles of airport staff or passengers which is outside the terminal building or sometimes under the ground of terminal building

4.16 Navigational aids, lighting, and marking

Only the simplest airfields are designed for operations conducted under visual meteorological conditions (VMC). These facilities operate only in daylight, and the only guidance they are required to offer is a painted runway centreline and large painted numbers indicating the magnetic bearing of the runway. Larger commercial airports, on the other hand, must also operate in the hours of darkness and under instrument meteorological conditions (IMC), when horizontal visibility is 600 metres (2,000 feet) or less and the cloud base (or “decision height”) is 60 metres (200 feet) or lower.

4.17 Navigational aids

The most common form of navaid used for the approach phase of aircraft descent is the instrument landing system (ILS). This is a radio signal that is beamed along the centreline of the runway and at the correct angle of approach (usually 3° above the horizontal). The beam is intercepted by an approaching aircraft up to 24 km (15 miles) from the threshold of the runway. Information is given concerning position above and below the glide slope and deviation to the right or left of centreline; consequently, the pilot is able to determine from cockpit instruments a deviation of the aircraft from the proper approach.

Additional approach information is given visually to the pilot in the form of lighting approach aids. Two systems of approach aids are in use: the visual approach slope indicator system (VASIS) and the more modern precision approach path indicator (PAPI). Both work on the principle of guiding lights that show white when the pilot is above the proper glide slope and red when below.

4.18 Airfield lighting

Visual guidance to approaching aircraft is also provided by approach lighting systems, a configuration of high-intensity white lights running along the centreline of the runway and extending up to 600 metres (2,000 feet) beyond the threshold. At airfields where aircraft operate in very poor visibility, touchdown-zone lighting is provided over the first 900 metres (3,000 feet) from the runway threshold. These lights, set in patterns flush with the runway pavement, provide guidance up to the final moment of touchdown.

The runway itself is strongly delineated by a variety of guidance light systems. The threshold is designated by a line of green lights, and the edges and centreline are delineated by white lights that shine toward the manufacturing aircraft at regular intervals. The pilot is warned of the approaching runway end by a line of red lights at the end of the usable pavement. Taxiways are delineated by blue edge lights and by green centreline lights that also appear at regular intervals.

4.19 Runway markings

Considerable additional visual guidance is given to pilots by painted markings on the runway. The form of marking indicates at a glance whether radio instrument guidance is available at any particular airfield. On precision instrument runways, the runway edges are indicated by painted lines, and distances along the runway from the threshold are indicated by pavement markings. In addition, touchdown-zone markings are painted on the pavement immediately after the threshold, providing vital visual guidance during the moments immediately before touchdown when all lighting may be obscured by fog.

4.20 Air traffic control

In the vicinity of airports—especially large airports, where in peak conditions as many as three landing or take-off operations may occur every minute—the control of aircraft in the air is a difficult but extremely important operation. Aircraft require very large amounts of airspace, but at the same time the risk of collision must be set at very low, almost negligible, levels. Because aircraft are concentrated in the airspace around airports, acceptable levels of collision risk can be achieved only by strict adherence to procedures that are set out and monitored by air traffic control authorities.

An aircraft in flight follows en route air traffic control instructions as it flies through successive flight information regions (FIRs). Upon approaching an airport at which a landing is to be made, the aircraft passes into the terminal control area (TCA). Within this area, there may be a greatly increased density of air traffic, and this is closely monitored on radar by TCA controllers, who continually instruct pilots on how to navigate within the area. The aircraft is then brought into the final approach pattern, at which point control passes to the approach controller, who monitors the aircraft to the runway itself. Once on the runway, the pilot is given instructions on ground manufacturer by the ground controller, whose responsibility is to avoid conflicting movements of aircraft in the operational area of the airfield. The ground controller gives the pilot instructions on reaching the apron stand position via the appropriate turnoffs and taxiways. Final positioning may be the responsibility of an apron controller. Departing aircraft go through a reverse procedure, whereby control is passed from ground control to departure control to terminal control area and, finally, to en route control.

4.20.1 Passenger terminal layout and design

As passenger throughput at airports increases, the passenger terminal becomes a more important element of the airport, attaining a dominant status in the largest facilities. The passenger terminal may amount to less than 10 percent of the total investment in a small airport, but at large airports terminals often account for more than 70 percent of infrastructural investment. The design that is ultimately adopted depends principally on the passenger volumes to be served and the type of passenger involved.

Passengers are frequently classified as business or leisure, scheduled or charter, originating or destined, and transfer or transit. Business travelers tend to pay significantly higher fares, and airlines usually wish to provide a high quality of service in order to attract such traffic. The passenger terminal at Heathrow Airport near London, for example, was designed to a very high standard of space and decor to attract just this type of passenger. Scheduled and charter passengers, meanwhile, tend to have very different needs in the terminal, especially at check-in and in the provision of ground transportation. Palma Airport, on the Spanish island of Majorca, has a landside that is designed to accommodate large numbers of charter tourists arriving and departing the airport by bus.

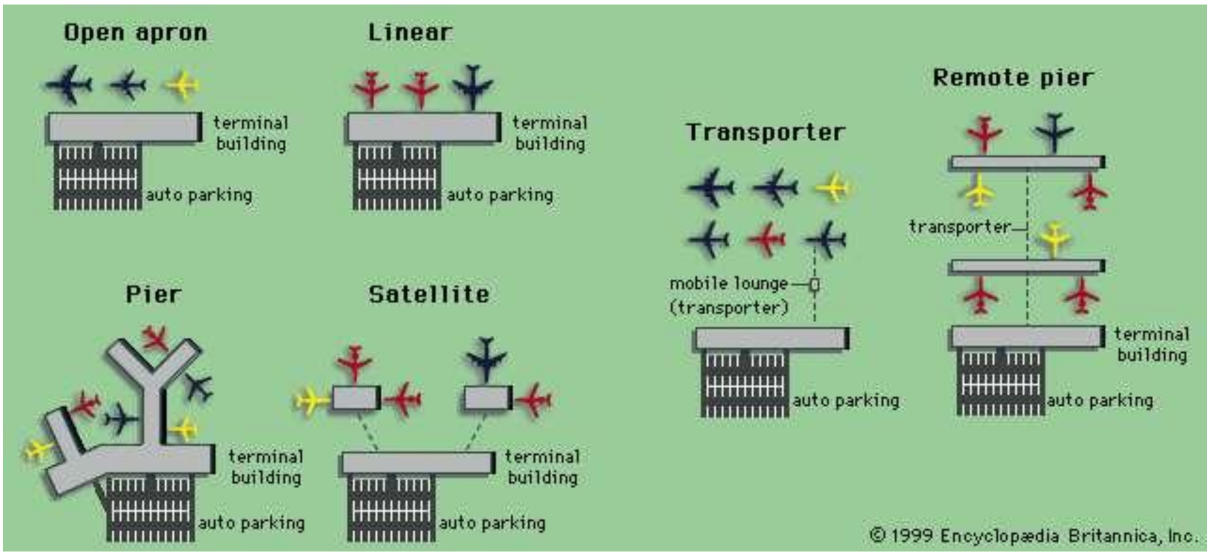
Some airports have a very high percentage of passengers who are either transiting the airport (i.e., continuing on the same flight) or transferring to another flight. At Hartsfield Atlanta International Airport in Georgia and at Chicago's O'Hare International Airport, for example, two-thirds of all passengers transfer to other flights and do not visit the cities where the airports are sited. These passengers have special needs but usually only on the airside of the terminal. There is no need to provide parking or ground transportation to the city for such passengers; they will, however, need transit lounges and other areas such as transit check-in desks.

Airports that receive a large number of transferring and transiting passengers are referred to as hubbing airports. At a hub, aircraft arrive in waves, and passengers transfer between aircraft during the periods when these waves are on the ground. By using a "hub-and-spoke" network, airlines are able to increase the load factors on aircraft and to provide more frequent departures for passengers—at the cost, however, of inconvenient interchange at the hub.

4.21 Terminal designs

4.21.1 Open apron and linear designs

The oldest and simplest layout for passenger terminals is the open apron design, in which aircraft park on the apron immediately adjacent to the terminal and passengers walk across the apron to board the aircraft by mobile steps. Frequently, the aircraft manufacture in and out of the parking positions under their own power. As airports grow, however, it is impossible to have large numbers of passengers walking across the apron. In this case, it is common to have terminals designed to the linear concept, with aircraft parked at gates immediately adjacent to the terminal itself. Usually, air bridges are employed for transferring passengers directly between the terminal building and the aircraft. The limitation of the linear concept is usually the long building dimensions required; these can mean long walking distances for transferring passengers and other complications related to building operation. In practice, building lengths tend to be limited to approximately 800 metres (2,650 feet). Examples of the linear design occur at Kansas City International Airport in Missouri, U.S., Munich Airport in Germany, and Charles de Gaulle Airport near Paris.



4.21.2 Pier and satellite designs

Where one building must serve a larger number of aircraft gates, the pier concept, originally developed in the 1950s, has been found very useful. Frankfurt International Airport in Germany and Schiphol Airport near Amsterdam still use such terminals. In the late 1970s, pier designs at Chicago's O'Hare and Atlanta's Hartsfield successfully handled in excess of 45 million mainly domestic passengers per year. However, as the number of aircraft gates grows, the distances that a passenger may have to travel within a pier-type terminal become exceedingly long, passenger circulation volumes become very large, and the terminal itself can become uncomfortable and unattractive to use. In order to cut down walking distances, some terminals, beginning in the 1960s, were designed on the satellite concept. Frequently, passengers are carried out to the satellites by some form of automated people mover or automatic train. Some satellite designs were very successful—for example, at Orlando and Tampa in Florida, U.S.—but to some degree the concept has fallen out of favour, having been found difficult to adapt to the changing size of aircraft and wasteful of apron space. Los Angeles International Airport originally had all its aircraft served at satellite buildings, but during the 1980s all satellites were converted to pier structures.

4.21.3 Transporter designs

In the early 1960s the transporter concept originated as a method of reducing aircraft manufacturing on the apron and of eliminating the need for passengers to climb up and down stairways in order to enter or exit the aircraft. In a concept derived from much older designs (such as that at Linate in Milan, where ordinary apron buses are used), passengers are brought directly to the aircraft by a specialized transporter vehicle. Mobile lounges used at Dulles International Airport near Washington, D.C., and at Jiddah's King Abdul Aziz International Airport have bodies that can be raised and lowered to suit the exact height of the terminal floor and the aircraft sill. However, passenger loading and unloading times are lengthened, causing turnaround delays, and aircraft are more likely to be damaged by the heavy lounges. For such reasons, this type of design has not proved popular with either passengers or airlines.

4.21.4 Remote pier designs

The remote pier was introduced at Atlanta's Hartsfield in the early 1980s. In this concept, passengers are brought out to a remote pier by an automatic people mover and there embark or disembark in the conventional manner. The system has proved very efficient for handling transfer passengers, but the long distances involved in the terminal layout necessitate the use of a sophisticated people-mover system. The design of the terminal at Stansted Airport near London incorporates this concept.

4.21.5 Unit terminals

The term *unit terminal* is used wherever an airport passenger terminal system comprises more than one terminal. Unit terminals may be made up of a number of terminals of similar design (e.g., Dallas–Fort Worth and Kansas City in the United States), terminals of different design (e.g., London's Heathrow, Pearson International Airport near Toronto, John F. Kennedy International Airport in New York City), terminals fulfilling different functions (e.g., Heathrow, Arlanda Airport near Stockholm, Barajas Airport near Madrid), or terminals serving different airlines (e.g., Paris's Charles de Gaulle, John F. Kennedy, Dallas–Fort Worth). The successful operation of unit terminal airports has often required the design of rapid and efficient automatic people movers such as those at Changi Airport in Singapore, at Dallas–Fort Worth, and at Houston Intercontinental Airport in Texas.

4.22 Cargo facilities

Less than 1 percent of all freight tonnage is carried by air. Nonetheless, this statistic significantly underestimates the importance of air freight because, in value of cargo moved, air transport dominates all other modes. For example, although Heathrow Airport handles only about a million tons of freight per year, in value of throughput it ranks as Britain’s premier port.

As is the case with passenger facilities, freight terminals vary greatly in the volumes of material handled. Consequently, the scale of the building facilities and the nature of the handling methods also vary. Because only 10 percent of air cargo is carried loose or in bulk, all modern air-cargo facilities are designed to handle containers. In countries where labour is cheap and where freight throughputs at the terminal are not high, freight-handling systems can still be economically designed around the manhandling concept. This is not feasible in developed countries, where labour costs are high. Even at facilities with small throughputs, freight is moved by mobile mechanical equipment such as stackers, tugs, and forklift trucks. At high-volume facilities, a mixture of mobile equipment and complex fixed stacking and movement systems must be used. The fixed systems, which require complex engineering design and maintenance, are known as transfer vehicles (TVs) and elevating transfer vehicles (ETVs).

In the design of air-cargo facilities, special attention must be given to the handling of very heavy and oversized freight, perishables, urgent materials such as serums and human donor organs, high-value goods such as diamonds and gold, hazardous goods, and livestock.

An area of very fast growth in the air-cargo business is specialized movement by integrated carriers such as the U.S.-based FedEx Corporation, which offer door-to-door delivery of small packages at premium rates. In its early years, this type of freight grew by more than 17 percent per annum. Cargo terminals for the small-package business are designed and constructed separately from conventional air-cargo terminals. They operate in a different manner, with all packages being cleared on an overnight basis.

4.23 Airport capacity

The various facilities at an airport are designed to cope adequately with the anticipated flow of passengers and cargo. The flow that any particular facility can accommodate without serious inconvenience to the users is considered to be its capacity. Limits on the traffic that can reasonably be accommodated at an airport are reached in a number of ways. These include air traffic delays to landing and take-off movements; congestion on runways, taxiways, and aprons; crowding and delays in terminal buildings; or severe congestion in such access facilities as parking areas, internal roads, and public transport.

At smaller one-runway airports, limits to capacity usually occur in the terminal areas, since the operational capacity of a single runway with adequate taxiways is quite large. When passenger volumes reach approximately 25 million per year, a single runway is unlikely to be adequate to handle the number of aircraft movements that take place during peak periods. At this point at least one additional runway, permitting simultaneous operation, is required. Airports with two simultaneous runways should be able to handle approximately 55 to 65 million passengers per year, and here, too, the main capacity problems are related to the provision of adequate terminal space. Layouts with four parallel runways are estimated to have operational capacities of well over one million aircraft movements per year and annual passenger movements in excess of 100 million. The main capacity constraints of such facilities are in the provision of sufficient airspace for controlled aircraft movements and in the provision of adequate access facilities. It is likely that many of the world's largest airports will face access problems before they reach the operational capacity of their runways.

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QUESTION BANK: TRANSPORT-II UNIT:1

Q-1) WHAT IS THE ROLE OF RAILWAY IN TRANSPORTATION?

Q-2) DESCRIBE HISTORICAL DEVELOPMENT OF RAILWAYS?

Q-3) WHAT IS PERMANENT WAY AND ITS COMPONENT? DRAW ITS NEAT AND CLEAN DIAGRAM.

Q-4) WHAT ARE GAUGES IN RAILWAYS AND ITS TYPES.

Q-5) WHAT IS CONING OF WHEEL? DESCRIBE THE FAILURE OF RAIL AND REQUIREMENT OF IDEAL RAIL.

Q-6) COMPARE RAIL TRANSPORTATION WITH ROAD TRANSPORTATION.

Q-7) COMPARE FLAT FOOTED RAILS WITH BULL HEADED RAILS.

Q-8) DEFINE CREEP OF RAIL? WHAT ARE ITS CAUSES, EFFECTS, AND ITS PREVENTION?

Q-9) EXPLAIN THE FUNCTIONS OF FISH PLATES AND FISH BOLTES. WHAT ARE ESSENTIAL REQUIREMENTS OF FISH PLATES.

Q-10) DESCRIBE THE FUNCTION AND REQUIREMENT OF RAILWAY TRACK.

Q-11) DESCRIBE THE SLEEPER DENSITY. WHAT ARE THE FUNCTION AND REQUIREMENTS OF SLEEPERS?

Q-12) WHAT ARE THE FUNCTION AND REQUIREMENTS OF BALLAST?

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QUESTION BANK: TRANSPORT-II UNIT:2

Q-1) DRAW A NEAT DIAGRAM OF SIMPLE RIGHT HAND OR LEFT HAND TURNOUT AND SHOW ITS VARIOUS COMPONENTS.

Q-2) WHAT ARE STATION AND YARDS. EXPLAIN IN BRIEF THEIR TYPES.

Q-3) WHAT IS MARSHALLING YARD WITH AID OF NEAT SKETCHES. EXPLAIN THE WORKING OF A MARSHALLING YARD.

Q-4) EXPLAIN THE NECESSITY OF GRADIENTS. DISCUSS ALL TYPES OF GRADIENTS GIVING PERMISSIBLE VALUES ADOPTED BY INDIAN RAILWAYS.

Q-5) WHAT ARE FUNCTIONS OF A RAILWAY STATIONS? DISCUSS THE VARIOUS REQUIREMENT OF A RAILWAY STATION.

Q-6) IF AN CURVE 8^* CURVE TRACK DIVERGES FROM A MAIN CURVE 5* IN AN OPPOSITE DIRECTION IN THE LAYOUT OF A B.G YARD, CALCULATE THE SUPERELEVATION AND THE SPEED OF BRANCH LINE, IF THE MAXIMUM SPEED PERMITTED ON THE MAIN LINE IS 45KMPH.

Q-7) ON A B.G CURVE, THE " EQUILIBRIUM CANT" IS PROVIDED FOR A SPEED OF 70KMPH.

a) CALCULATE THE VALUE OF EQUILIBRIUM CANT
b) ALLOWING A MAXIMUM CANT DEFICIENCY, WHAT WOULD BE THE MAXIMUM PERMISSIBLE SPEED ON THE TRACK.

Q-8) WHAT WOULD BE THE PERMISSIBLE SPEED ON THE CURVE? IF ON A 8* M.G TRACK, THE AVERAGE SPEED OF DIFFERENT TRAINS IS 50 KMPH AND ALLOWABLE CAN DEFICIENCY IS HALF THAT OF MAXIMUM CANT DEFICIENCY.

Q-9) WHAT ARE CROSSINGS, THEIR TYPES? EXPLAIN OBTUSE ANGLE CROSSING OR DIAMOND CROSSING.

Q-10) ON A STRAIGHT B.G TRACK, A TURNOUT TAKES OFF AT AN ANGLE OF 6*42'35", DESIGN THE TURNOUT WHEN IT IS GIVEN ANGLE OF SWITCH= 1*34'27", THE LENGTH OF SWITCH RAILS IS 4.73m, HEEL DIVERGENCE i.e. d= 11.43cm AND x, i.e. STRAIGHT ARM= 0.85m.

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QUESTION BANK: TRANSPORT-II UNIT:3

Q-1) MENTION THE VARIOUS STEPS NEEDED FOR MODERNIZING THE RAILWAY TRACK FOR RUNNING HIGH SPEED TRAINS IN INDIA.

Q-2) DESCRIBE THE VARIOUS METHODS OF HARD ROCK TUNNELING AND MENTION THE ADVANTAGE AND DISADVANTAGES OF EACH OF THEM.

Q-3) WRITE SHORT NOTE ON THE FOLLOWING:

a) MRS
b) ATS
c) INTERLOCKING

Q-4) EXPLAIN ANY ONE METHOD OF CONSTRUCTION OF TUNNELS IN HARD AND SOFT ROCKS.

Q-5) NAME THE DIFFERENT METHODS OF SOFT GROUND TUNELLING AND DESCRIBE ANY OF THEM IN DETAIL.

Q-6) WRITE SHORT NOTES ON FUTURE OF HIGH SPEED TRAINS IN INDIA.

Q-7) WHAT IS INTERLOCKING. DESCRIBE THE NECESSITY AND FUNCTION OF INTERLOCKING. EXPLAIN THE METHODS OF INTERLOCKING.

Q-8) DEFINE TUNNELS. WHAT ARE ADVANTAGES AND DISADVANTAGES OF TUNNELS.

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QUESTION BANK: TRANSPORT-II UNIT:4

Q-1) COMPARE AIR TRANSPORT WITH OTHER MODES OF TRANSPORT.

Q-2) DRAW THE NEAT SKETCHES, THE VARIOUS MARKING ON RUNWAYS.

Q-3) WHAT DO YOU MEAN BY TERM AIRPORT CAPACITY. WHAT ARE THE FACTORS WHICH AFFECT THE AIRPORT CAPACITY?

Q-4) EXPLAIN THE PROCEDURE OF ORIENTING THE RUNWAY.

Q-5) EXPLAIN THE NECESSITY OF AIRPORT LIGHTNING.

Q-6) EXPLAIN BRIEFLY THE VARIOUS FACTORS WHICH AFFECT THE LAYOUT OF TAXIWAY.

Q-7) ENUMERATE THE VARIOUS FACTORS WHICH YOU WOULD KEEP IN VIEW WHILE SELECTING A SUITABLE SITE FOR AN AIRPORT.

Q-8) DEFINE:

a) APRON AREA
b) HANGER
c) BASIC RUNWAY LENGTH
d) TURNING ZONE.