CE 4505: Railway, Airport and Harbour Engineering

MD Ehasan Kabir

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COURSE INFORMATION
Railway, Airports and Harbour Engineering
MD Ehasan Kabir

No.	Course Learning Outcomes
CLO1	Explain the principles of civil engineering as applied to transportation infrastructure.
CLO2	Describe the historical development and significance of railways, airports, and harbors.
CLO3	Identify the key components and subsystems of each mode of transportation.
CLO4	Design railway tracks, considering factors like traffic loads, soil conditions, and safety standards.
CLO5	Plan and design airports, considering site selection, capacity, and environmental impact.

Week	Topic	Teaching Learning Strategy	Assessment Strategy	Corresponding CLOs
01	Introduction to Airport Engineering	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO5
02	Components of an Airport	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO5

03	Airport Planing Studies	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO5
04	Airport Configuration	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO5
05	Site Selection Approach	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO5
06	Air Traffic Control Facilities	Lecture, Oral presentation	Class Test	CLO1, CLO2, CLO3, CLO5
07	Airport Aids and Markings	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO5
08	Airport Lightings	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO5
09	Air Safety and Regulations	Lecture, Oral presentation	Class Test	CLO1, CLO2, CLO3, CLO5
10	Curvature of Track	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO4
11	Maintenance	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3,

				CLO4
12	Point and Crossings	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO4
13	Train Resistance and Tractive Power	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO4
14	Railway Track Gauge and Rails	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO4
15	Track Fittings and Fastenings	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO4
16	Sleepers and Ballast	Lecture, Oral presentation	Daily Quiz, Sudden test	CLO1, CLO2, CLO3, CLO4
17	Railway Stations and signaling	Lecture, Oral presentation	Class Test	CLO1, CLO2, CLO3, CLO4

Week-(01)

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Course Outline

- Pavement management systems; evaluation and strengthening of pavements; drainage: highway drainage and drainage structures; **airports: importance, advantages and trends in air transportation, planning and design of airports, aircraft characteristics related to airport design, types and elements of airport planning studies, airport configuration, geometric design of the landing area, terminal area, heliports, design of** airport pavements**, lighting, marking and signing**, airport drainage.

Reference Materials

- **Planning and design of airports** by Robert Horonjeff
- Acknowledgement to Dr. M. K. Mohan B.E., M.E., Ph.D., MISTE, MISCA, Professor of Civil Engineering, GNITC, Hyderabad

Topic: The Air Transportation Systems

1. Introduction and History
2. Growth of Air Transport and Future Trends
3. Aviation Organizations and their Functions

Air Transportation (Advantage)

- Improves accessibility to otherwise inaccessible areas
- Provides continuous connectivity over land and water (No change of equipment)
- Brings in relief during emergency conditions
- Saves productive time spent in journey
- Increases the demand of specialized technical skill workforce
- Adds to foreign reserve through tourism etc.

Air Transportation (Problems)

- Heavy funds are required, not only initially but also during operations
- Operation are highly dependant up on weather conditions
- Required heavy sophisticated machinery
- Adds outward flow of foreign exchange
- Safety provisions are not adequate
- Specific demarcation of flight paths and territories is essential

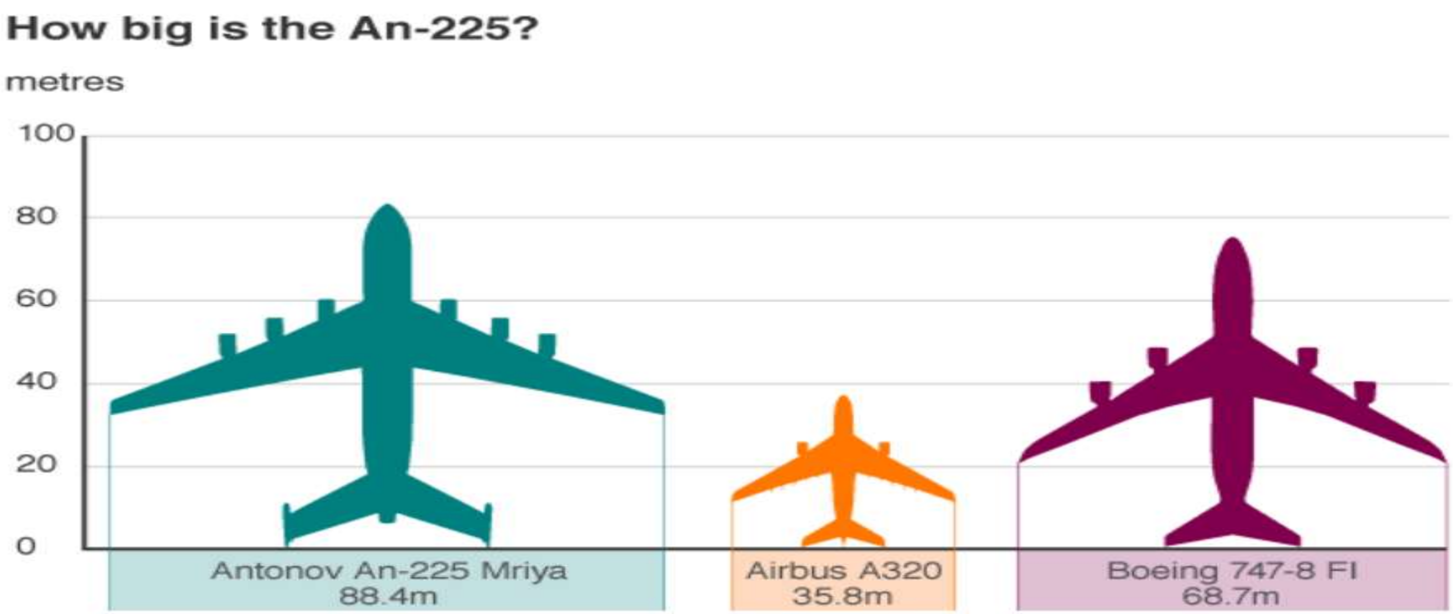
History of Air Transport

1. 126 AD - Reger Bacon was the first man to study the flight of birds and made a prophecy that the source of energy for flight can be derived from fire.
2. December 17, 1903 AD – First Air flight was made by Wright brothers. Orville Wright – A bicycle repairman has propelled himself through the air for a distance of 35 m in North Carolina State, USA.
3. 1914-18 AD – Zeppelin aeroplanes were used by Germany for Passengers.
4. 1918 , May - Long distance mail service was started between Washington and New York.
5. 1919 AD – First international flight was started between Toulose in France to Barcelona in Spain.
6. 1927 AD – Lindburg made first solo flight between New York to Paris.
7. 1939 August 27 – First Jet Flight was made in Germany.

The First Airport in the History

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

World's Biggest Plane Antonov An-225



Antonov An-225

- The wide body Antonov An-225 is powered by six turbofan engines and is the longest and heaviest airplane ever built, with a maximum takeoff weight of 640 tonnes.
- It was built to carry Soviet space shuttles and, 27 years after it entered service, it's still the world's biggest plane.
- The An-225, better known as the Mriya (Ukrainian for "dream") creates a fuss wherever it goes.
- Measuring 84 m long with an 88 m wingspan, it weighs 175 tonnes without cargo or fuel.
- It's the longest-bodied, longest-winged and heaviest operational plane in the world.
- Its cargo compartment is 43 m by 6.4 m by 4.4 m – big enough to hold 50 cars. And there is only one operational Antonov An-225 in the world!

What is Efficient Transportation System?

- Efficient transportation system means carrying passengers and goods from one place to other place at

  1. Low cost
  2. Less travel time
  3. whenever needed
  4. wherever needed
  5. Comfort
  6. Safety

In respect of above points,

Air transport becomes most efficient transportation system than other modes of transportation systems.

Aviation Organizations

1. International Civil Aviation Organization (ICAO)
2. International Air Transport Association (IATA)
3. Federal Aviation Administration (FAA)
4. **Civil Aviation Authority of Bangladesh (CAAB)**

The International Civil Aviation Organization (ICAO)

- The International Civil Aviation Organization (ICAO) serves as an agency through which the necessary international understanding and agreement between nations in all the technical, economical and legal issues and codifies the principles and techniques of international air navigation and fosters the planning and development of international air transport to ensure safe and orderly growth.
- It was created in 1944 and it became a special UN agency in 1947. It has membership of 151 countries.
- ICAO is headquartered at Montreal in Canada and is headed by a Secretary General
- It has 7 regional offices at 1) Paris 2) Mexico city 3) Bangkok 4) Cairo 5) Dakar 6) Lima 7) Nairobi

International Air Transport Association (IATA)

- The **International Air Transport Association** (**IATA)** is a trade association of the world's airlines with a membership of 250 major carriers in the world. They carry approximately 84% of total available seat kilometers of air traffic.
- IATA supports airline activity and helps formulate industry policy and standards.
- It is headquartered in Montreal, Canada with Executive Office at Geneva in Switzerland.

Federal Aviation Administration (FAA)

- The **Federal Aviation Administration** (**FAA**) is the national aviation authority of the United States.
- An agency of the United States Department of Transportation, it has authority to regulate and oversee all aspects of American civil aviation.

Functions of FAA include:

1. Regulating U.S. commercial space transportation
2. Regulating air navigation facilities' geometry and flight inspection standards
3. Encouraging and developing civil aeronautics, including new aviation technology
4. Issuing, suspending, or revoking pilot certificates
5. Researching and developing the National Airspace System and civil aeronautics
6. Developing and carrying out programs to control aircraft noise and other environmental effects of civil aviation

Civil Aviation Authority, Bangladesh (CAAB)

- Civil Aviation Authority, Bangladesh (CAAB) functions as the regulatory body for all aviation related activities in Bangladesh. It is the national aviation authority operating under the Ministry of Civil Aviation & Tourism.
- All nine operational airports (three international and six domestic) are operated by the CAAB. A member of International Civil Aviation Organization (ICAO), it has signed bilateral air transport agreement with 52 states. It is headquartered in Kurmitola, Dhaka.

THREE INTERNATIONAL AIRPORTS

There are three International Airports in the country.

1. Hazrat Shahjalal International Airport, Dhaka

This is the largest and the principal international airport of the country. It is situated at the capital city Dhaka. Almost all international passengers embark at and disembark from HSIA. More than 90% of aeronautical functions of CAAB is carried out from it.

2. Shah Amanat International Airport, Chattogram

This airport is situated in the port city of Chattogram. It is the second largest airport and the alternate airport to HSIA.

3. Osmani International Airport, Sylhet

It is situated at the city of Sylhet, a district at the North-East corner of the country. It has been upgraded to an international one in order to facilitate the people of the district which is famous for a large number of residents of United Kingdom.

TWELVE DOMESTIC AIRPORTS

A. Operational- (5)

1. Cox's Bazar Airport
2. Shah Makhdum Airport, Rajshahi,
3. Jashore Airport
4. Saidpur Airport
5. Barishal Airport

B. Needs prior approval for air operation-(3)

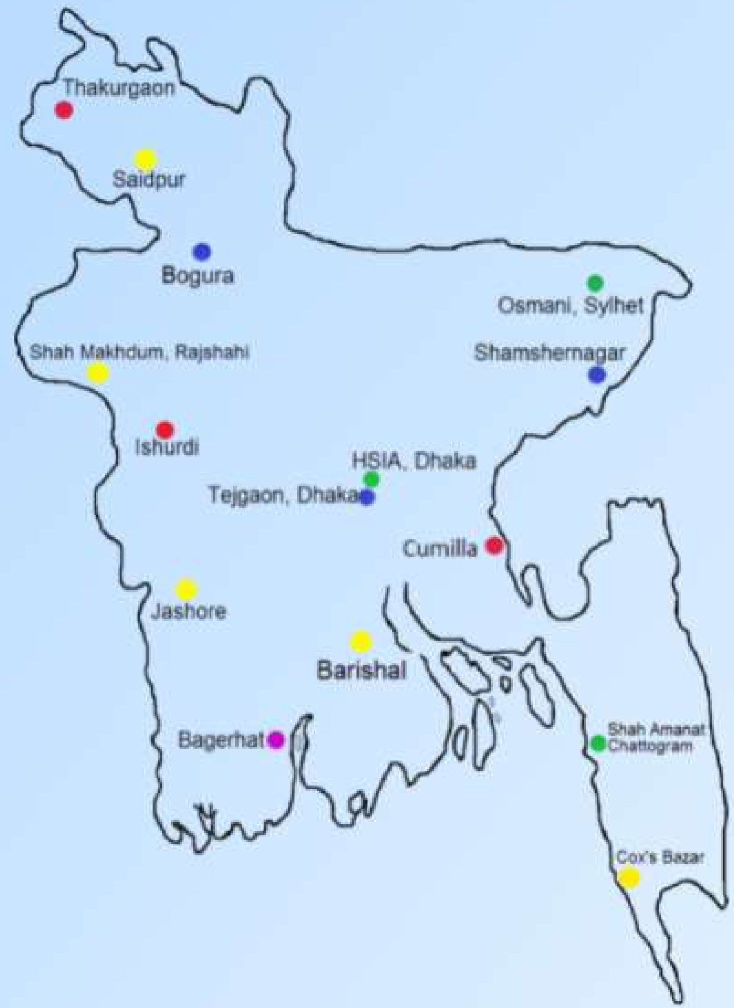
1. Tejgaon Airport
2. Bogura Airport
3. Shamshernagar Airport (STOL)

C. Service not available-(3)

1. Ishurdi Airport
2. Cumilla Airport (STOL)
3. Thakurgaon Airport.

UNDER CONSTRUCTION

Khan Jahan Ali Airport, Bagerhat.



Legend under Bangladesh Map:

1. Green - International Airports
2. Yellow - Domestic Operational Airports
3. Blue - Airports where prior approval is needed for air operation.
4. Red - Airports where service is not available
5. Purple - Airport under construction.

- Freight data was reported at 86.376 million Ton-km in 2019.
- This records an increase from the previous number of 50.617 million Ton-km for 2018.
- Freight data is updated yearly, averaging 83.200 million Ton-km from Dec 1973 to 2019, with 47 observations.
- The data reached an all-time high of 225.187 million Ton-km in 2013 and a record low of 0.013 Ton-km mn in 2009.

- Passengers Carried data was reported at 5,959,126.000 Person in 2019.
- This records an increase from the previous number of 5,677,396.000 Person for 2018. : Passengers Carried data is updated yearly, averaging 1,215,900.000 Person from Dec 1973 to 2019, with 47 observations.
- The data reached an all-time high of 5,959,126.000 Person in 2019 and a record low of 431,400.000 Person in 1974.

- Registered Carrier Departures Worldwide data was reported at 58,497.000 Unit in 2019.
- This records an increase from the previous number of 53,061.000 Unit for 2018. Registered Carrier Departures Worldwide data is updated yearly, averaging 13,500.000 Unit from Dec 1973 to 2019, with 47 observations.
- The data reached an all-time high of 70,503.000 Unit in 2017 and a record low of 5,900.000 Unit in 1999.

Airline	Image	IATA	ICAO	Callsign	Hub airport(s)
Biman Bangladesh Airlines[1]		BG	BBC	BANGLADESH	• Shahjalal International Airport • Shah Amanat International Airport • Osmani International Airport
US-Bangla Airlines[2]		BS	UBG	BANGLASTAR	• Shahjalal International Airport
Regent Airways[3]		RX	RGE	REGENT	• Shahjalal International Airport
Novoair[3]		VQ	NVQ	NOVOAIR	• Shahjalal International Airport
Air Astra[4]					• Shahjalal International Airport

Thanks!

Week-(02)

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Topic: Components of Air Transportation

1. Airports and Airways
2. Airlines and Air Passengers
3. Operating Environment

Components of Air Transportation

- Aircraft Characteristics
- Any machine which finds its support in the atmosphere due to reactions of the air is defined as an aircraft.
- Aircraft can be heavier or lighter than air or power driven or non-power driven.
- For example, airships are lighter than air and are power driven.
- Similarly, Balloons are lighter than air and are non-power driven
- Aeroplanes and Helicopters are heavier than air and are power driven.

Aeroplane and Helicopter

- The airplane is the most practical type of machine to navigate in the air and thousands of them are in daily use.
- They are designed to take off and land on runways with much steeper angles than the helicopters.
- The helicopter can rise vertically off the ground and can also hover stationary in the air.
- Helicopters have inferior performance compared to the aeroplanes as their load capacity is extremely small and their top speed is very low.
- Airplanes can also be designed to operate on water. They are called float planes.
- Float planes have long pontoon floats on which it rests when it is on water
- Amphibian planes can have both floats and wheels.

Airports and Airways

- An **airport** is an aerodrome with facilities for commercial aviation flights to take off and land. Airports often have facilities to store and maintain aircraft, and a control tower.

- An **airway** is a legally defined corridor that connects one specified location to another at a specified altitude, along which an aircraft that meets the requirements of the airway may be flown.

Types of Airports

- There are three types of Airports

1. International Airports
2. Domestic Airports
3. Regional Airports

International Airports

- An international airport has direct service to many other airports.
- Handle scheduled commercial airlines both for **passengers and cargo.**
- Many international airports also serve as "HUBS", or places where non-direct flights may land and passengers switch planes.
- Typically equipped with customs and immigration facilities to handle international flights to and from other countries.
- Such airports are usually larger, and often feature longer runways and facilities to accommodate the large aircraft. (FBO, MRO etc..)

Domestic Airports

- A domestic airport is an airport which handles only domestic flights or flights within the same country.
- Domestic airports don't have customs and immigration facilities and are therefore incapable of handling flights to or from a foreign airport.
- These airports normally have short runways which are sufficient to handle short/medium haul aircraft.

Regional Airports

- A regional airport is an airport serving traffic within a relatively small or lightly populated geographical area.
- A regional airport usually does not have customs and immigration facilities to process traffic between countries.
- Aircraft using these airports tend to be small business jets or private aircraft (general aviation)

Airlines and Air Passengers

- An organization providing a regular public service of air transport on one or more routes with its equipment and operating personnel is called Airlines.
- Persons who are travelling in any public transport aircraft other than its pilot and airline staff members are called Air Passengers.

Operating Environment

- Airlines must be aware of and operate within a framework of regulations, standards and guidelines, international agreements and programs that shape the operating environment for commercial aviation.

Thanks!

Week-(03)

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Topic: Airport Planning

1. Types of Airport Planning Studies
2. Forecasting in Aviation and Airport Planning

Airport Planning

- Airport Planning involves

  1. Preparation of Master Plan
  2. Layout Plans

Types of Airport Planning Studies

- There are various types of airport planning studies which are to be carried out before carrying out construction of an airport

1. Technical feasibility studies
2. Forecasting requirement studies
3. Facilities Planning
4. Financial Planning
5. Economic Planning
6. Organizational Planning
7. Strategic planning
8. Environmental Planning

Types of Airport Planning Studies

1. **Engineering and Technical Planning Studies:**

   These studies involve various activities like Approach zone surveys, Drainage surveys, Meteorological Surveys, Natural Resources Surveys, Soil Surveys, Topographical Surveys and Traffic Surveys.

2. **Forecasting Requirement Studies:**

   These studies involve determining parameters like Annual Passenger Volume, Annual volume of aircrafts, Peak day and peak hour volume of passengers and aircrafts, Air Cargo, Air mail and General Aviation etc.

Types of Airport Planning Studies

3. **Facilities planning**: which focuses on future needs for airfield infrastructure such as runways, taxiways, aircraft parking facilities, associated lighting, communication and navigational systems, terminal buildings and facilities, parking lots, ground access infrastructure, and support facilities such as fuel farms, power plants, and non-aeronautical land uses such as office parks, hotels, restaurants, or rental car locations.

4. **Financial planning**: which is concerned with predicting future revenues and expenses, budgeting resources, and planning for financial assistance through grant programs, bond issues, or private investment.

5. **Economic planning**: which considers the future of economic activity, such as trade and commerce, and the activity of industries that exist on airport and off-airport property and are either a direct or indirect result of airport operations.

Types of Airport Planning Studies

6. **Organizational planning**: which entails the management of future labour requirements and organizational structures for the airport administration, staff, and associated labor force.

7. **Strategic planning**: which encompasses all other planning activities into a coordinated effort to maximize the future potential of the airport to the community.

Types of Airport Planning Studies

8. Environmental planning: which concentrates on maintaining or improving existing environmental conditions in the face of changes in future airport activity. Environmental planning includes land use planning, noise mitigation, wetland reclamation, and wildlife preservation.

The environmental factors must be carefully considered in the development of a new airport or the expansion of an existing one. In this connection, the following three studies are made to assist the project authorities in planning the airports.

1. Environmental Impact Assessment (EIA)
2. Environmental Impact Statement (EIS)
3. Environmental Management plan (EMP)

Forecasting in Aviation and Airport Planning

The reliable predictions of the airport activity in respect of the following parameters are to be made.

1. Annual Passenger Volume
2. Annual volume of aircrafts
3. Peak day and peak hour volume of passengers and aircrafts
4. Air Cargo
5. Air mail
6. General Aviation

Important Components of an Airport

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

1. Runways

A runway is the area or a platform where an aircraft lands or takes off.

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

Runway

2. Terminal Buildings

- Also known as airport terminal, these buildings are the spaces where passengers board or alight from flights. These buildings house all the necessary facilities for passengers to check-in their luggage, clear the customs and have lounges to wait before disembarking. The terminals can house **cafes**, lounges and **bars** to serve as waiting areas for passengers.

- Ticket counters, luggage check-in or transfer, security checks and customs are the basics of all airport terminals. Large airports can have more than one terminal that are connected to one another through link ways such as walkways, sky-bridges. Smaller airports usually have only one terminal that houses all the required facilities.

Terminal Building

3. Aprons

- Aircraft aprons are the areas where the aircrafts are parked, unloaded, refueled or boarded. Aprons are also sometimes called ramps. They vary in size, from areas that may hold five or ten small planes, to the very large areas that the major airports have.

- Although the use of the apron is covered by regulations, such as lighting on vehicles, it is typically more accessible to users than the runway or taxi way. However, the apron is not usually open to the general public and a license may be required to gain access.

4. Taxiway

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

5. Aircraft Stand

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

6. Hangar

- A **hangar** is a closed building structure to hold aircraft in protective storage. Most hangars are built of metal, but other materials such as wood and concrete are also used.
- Hangars are used for protection from the weather, protection from direct sunlight, maintenance, repair, manufacture, assembly and storage of aircraft on airfields, aircraft carriers and ships.

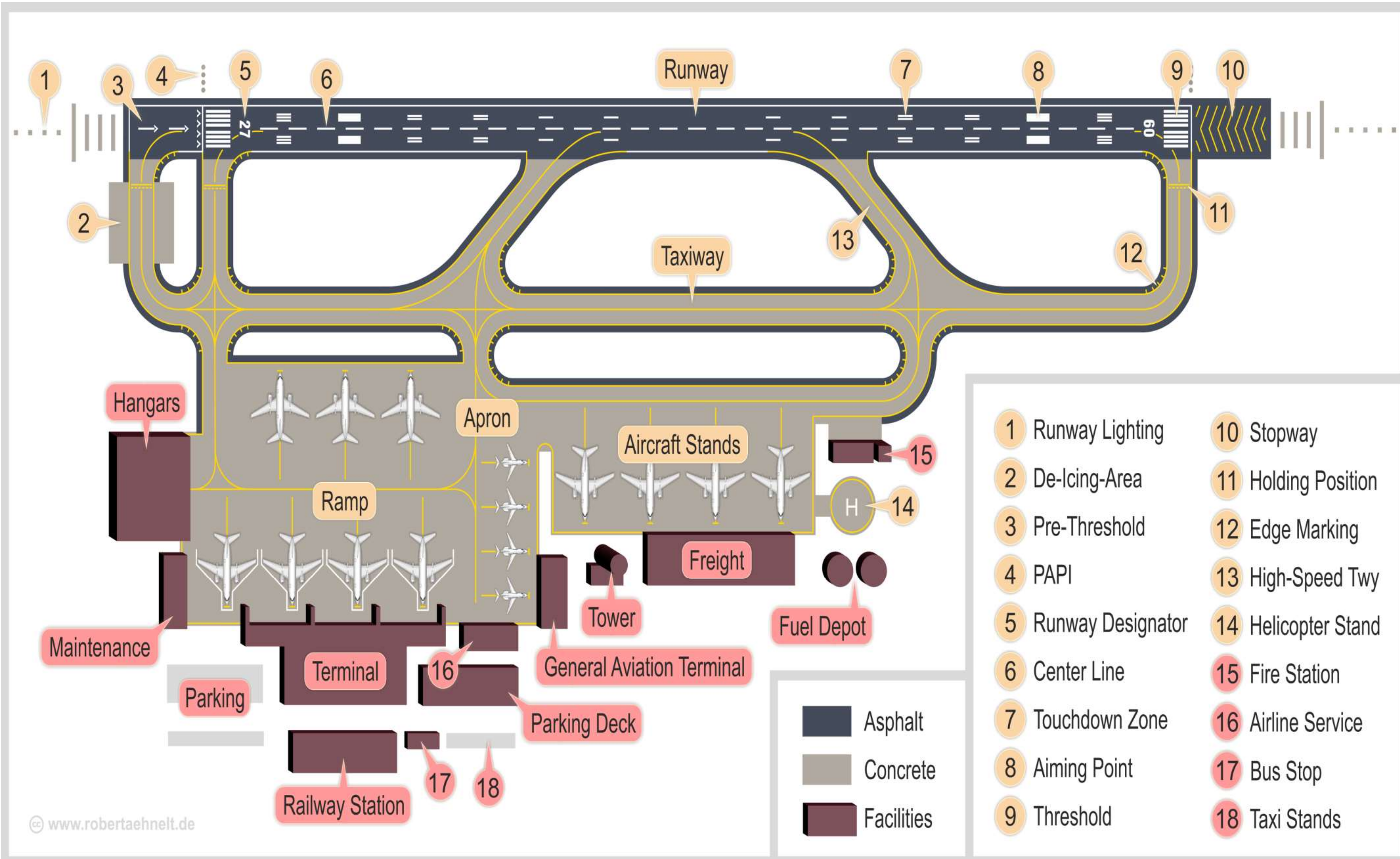
7. Air Traffic Control Tower

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

8. Parking

- Parking is a specific area of airport at which vehicles park.

Typical Layout of an Airport



Thanks!

Week-(04)

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Topic: Airport Configuration

1. Runway Configurations
2. Taxiway Configurations

FACTORS AFFECTING RUNWAY ORIENTATION

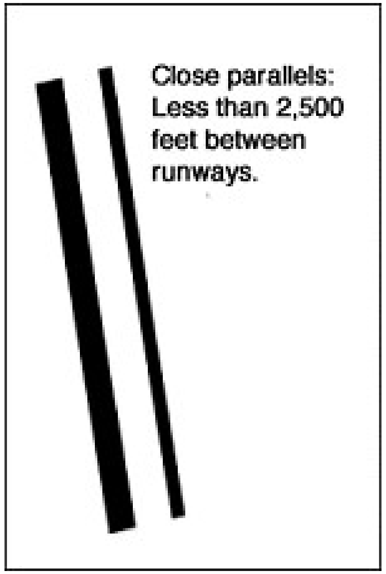
- WIND
- AIRSPACE AVAILABILITY
- ENVIRONMENTAL FACTORS
- OBSTRUCTIONS TO NAVIGATION
- AIR TRAFFIC CONTROL VISIBILITY
- WILD LIFE HAZARDS
- TERRAIN AND SOIL CONSIDERATION

Runway Configurations

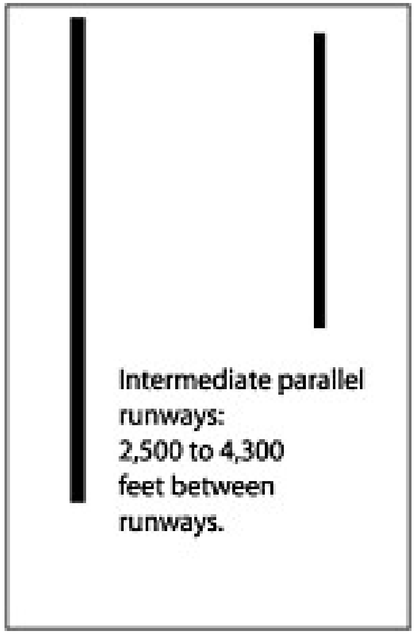
- Many runway configurations are existing.
- Most of them are combinations of the following basic configurations:
  - Single runway
  - Parallel Runways
    - Two parallel runways
    - Two parallel runways with staggered thresholds
    - Four parallel runways
  - Open-V Runways
  - Intersecting runways

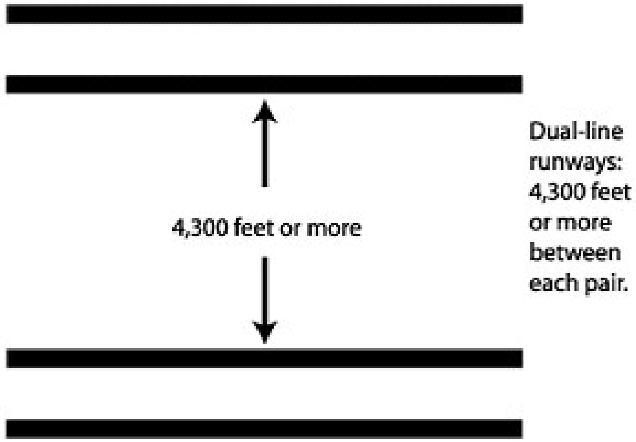
Single Runway

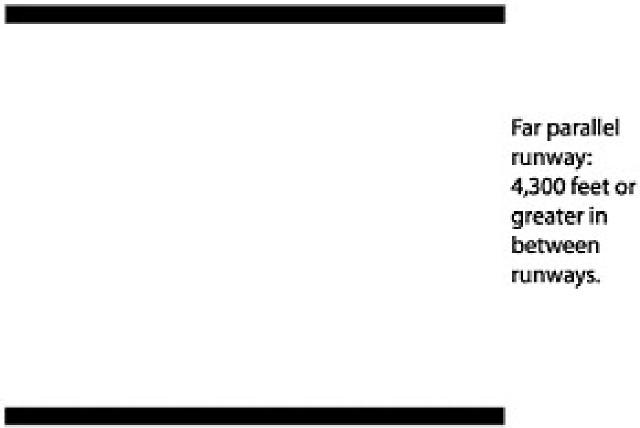
PARALLEL RUNWAYS



There are 4 types of parallel runways

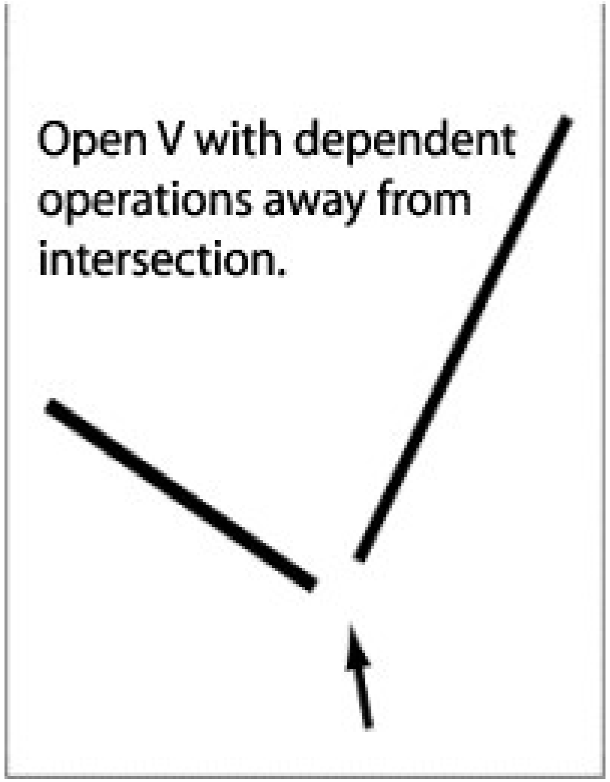


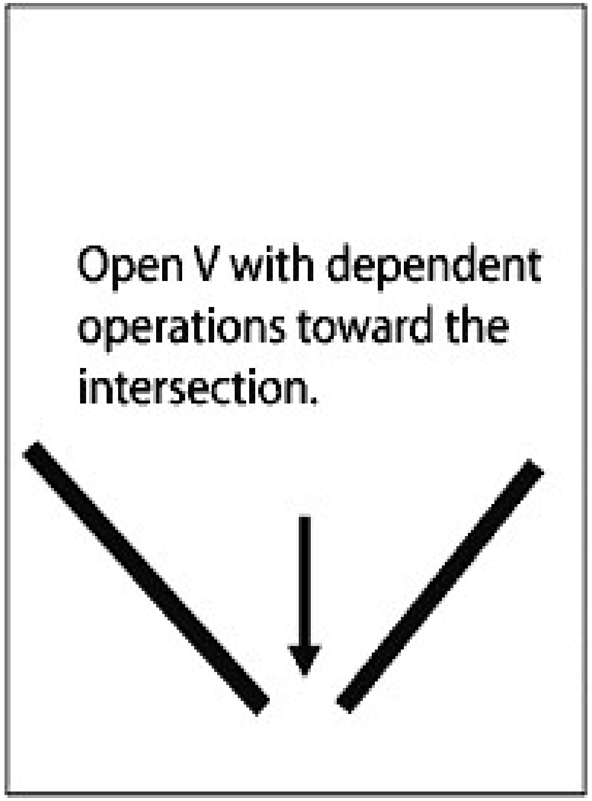




OPEN-V RUNWAYS

Runways diverging from different directions but do not intersect and form an open-V shape are 'OPEN-V runways'

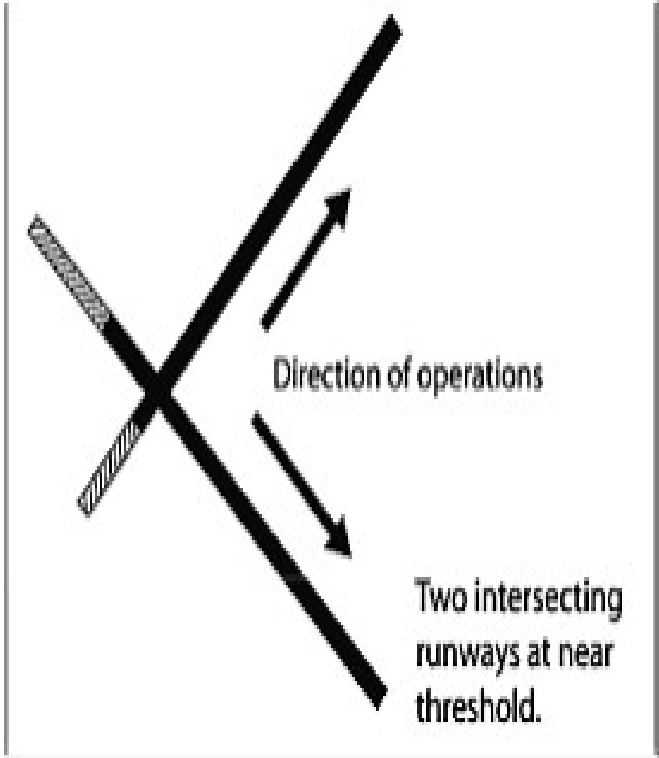


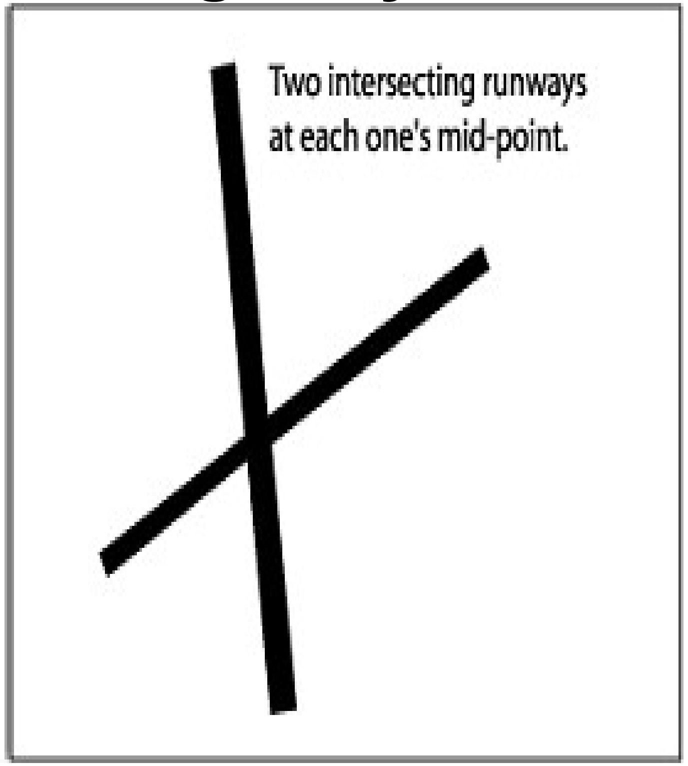


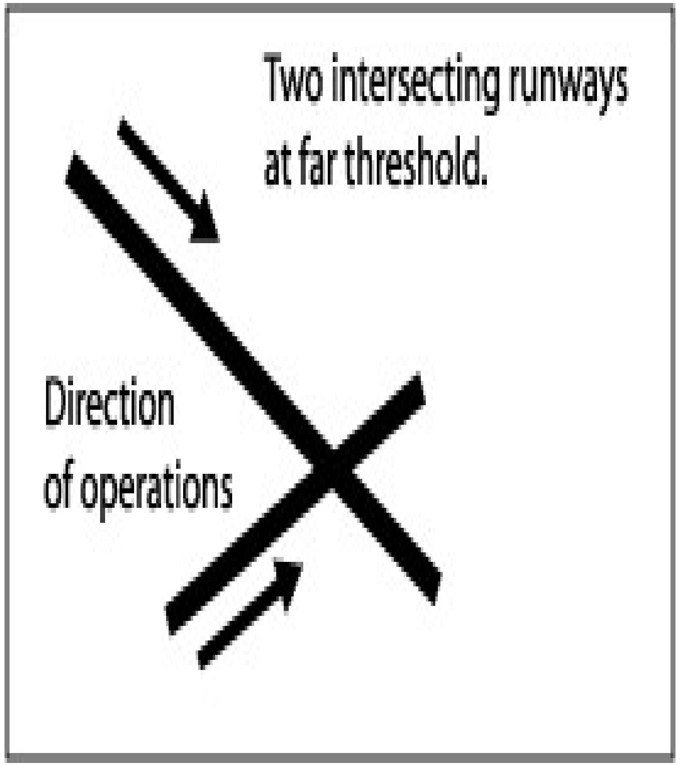
INTERSECTING RUNWAYS

Two or more runways that cross each other are classified as intersecting runways.

This type of runway is used when there are relatively strong prevailing winds from more than one direction during the year.







Shahjalal International Airport

San Francisco International Airport

Zurich Airport

Chicago-Midway Airport


200 ft
100 m
Imagery ©2011 DigitalGlobe, GeoEye, U.S. Geological Survey, USDA Farm Service Agency, Map data ©2011 Google -
Edit in Google Map Maker

Designator?

Taxiway Configurations

- Studies based on empirical results show that the capacity of a taxiway system generally far exceeds the capacities of runways.

Taxiway Configuration

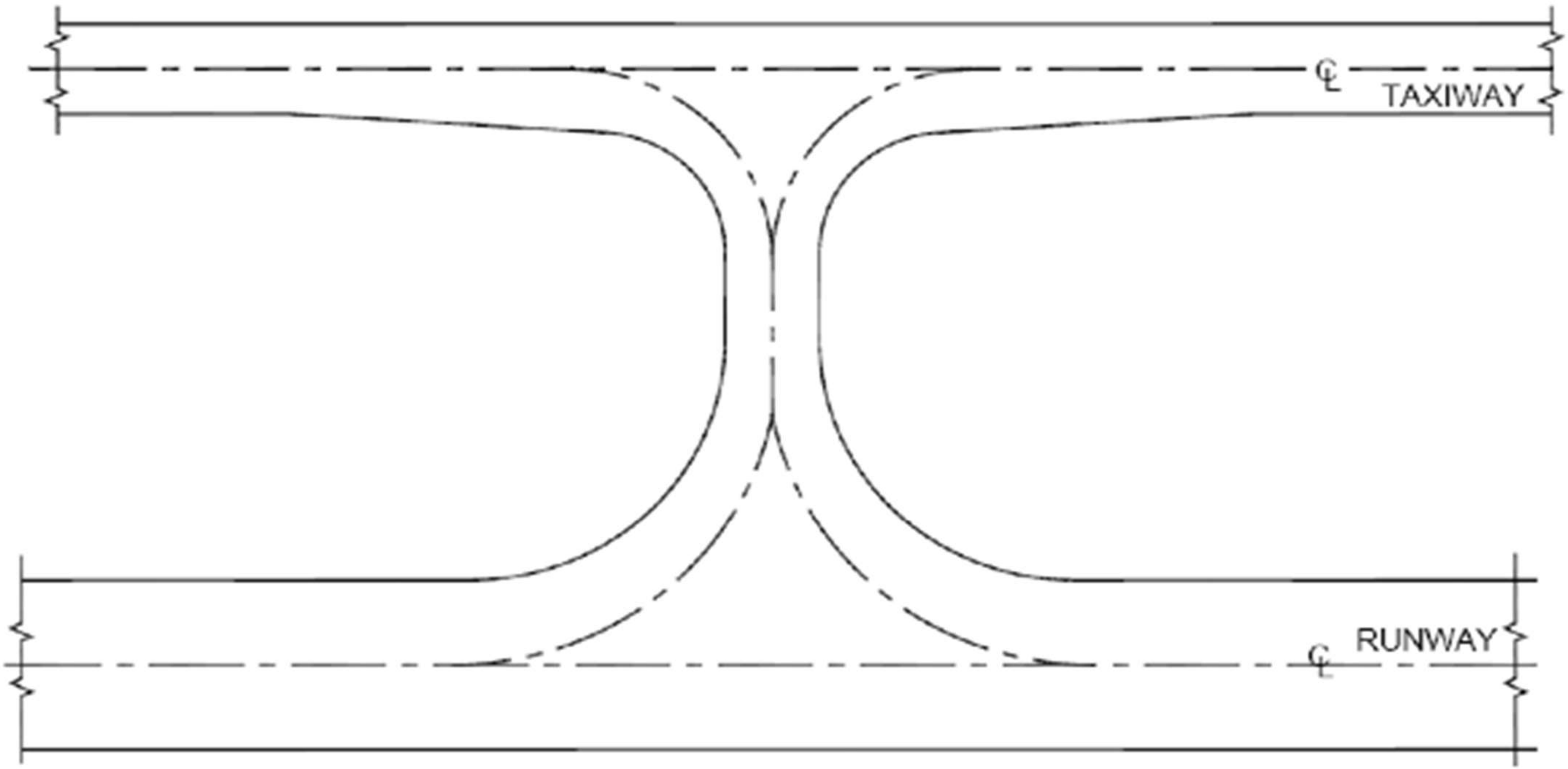
- The movement of aircrafts to and from the runways and the terminal/cargo, and parking areas is provided by a system of **taxiways**.

- This system of taxiways includes
  - *Entrance and exit taxiways*
  - *Parallel taxiways*
  - *Bypass taxiways*

Exit Taxiways

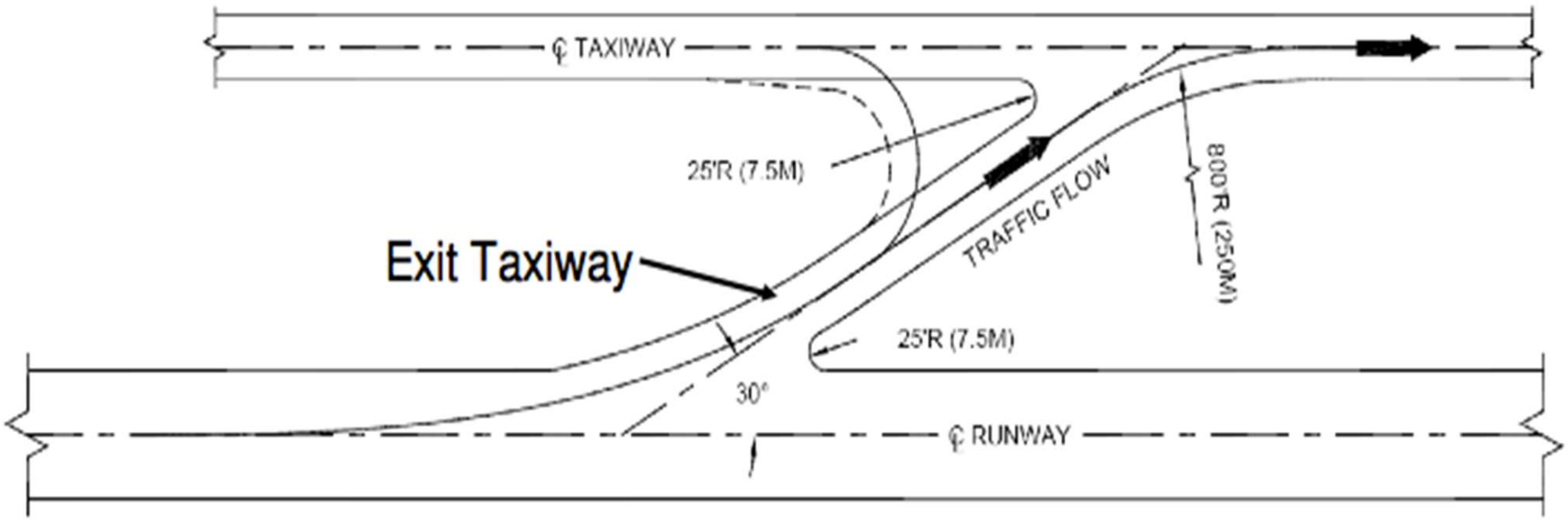
- These are taxiways provided at appropriate locations along the length of runway so that the landing aircrafts can maneuver out of the runway minimising their runway occupancy time.
- Right angled exit taxiways:
    - These are exit taxiways placed at right angles to the runway. When the design peak hour traffic is less than 30 operations (landings and takeoffs), a properly located right- angled exit taxiway will achieve an efficient flow of traffic.
- High speed exit taxiways:
    - These exit taxiways are placed at acute angle to the runway and are designed to provide high exit (turnoff) speeds. These high speed exit taxiways when properly designed in terms of their number, location and exit speed can enhance the capacity of the runway.

Typical Right Angled Exit Taxiway



Source: FAA AC: 150/5300-13 (1989)

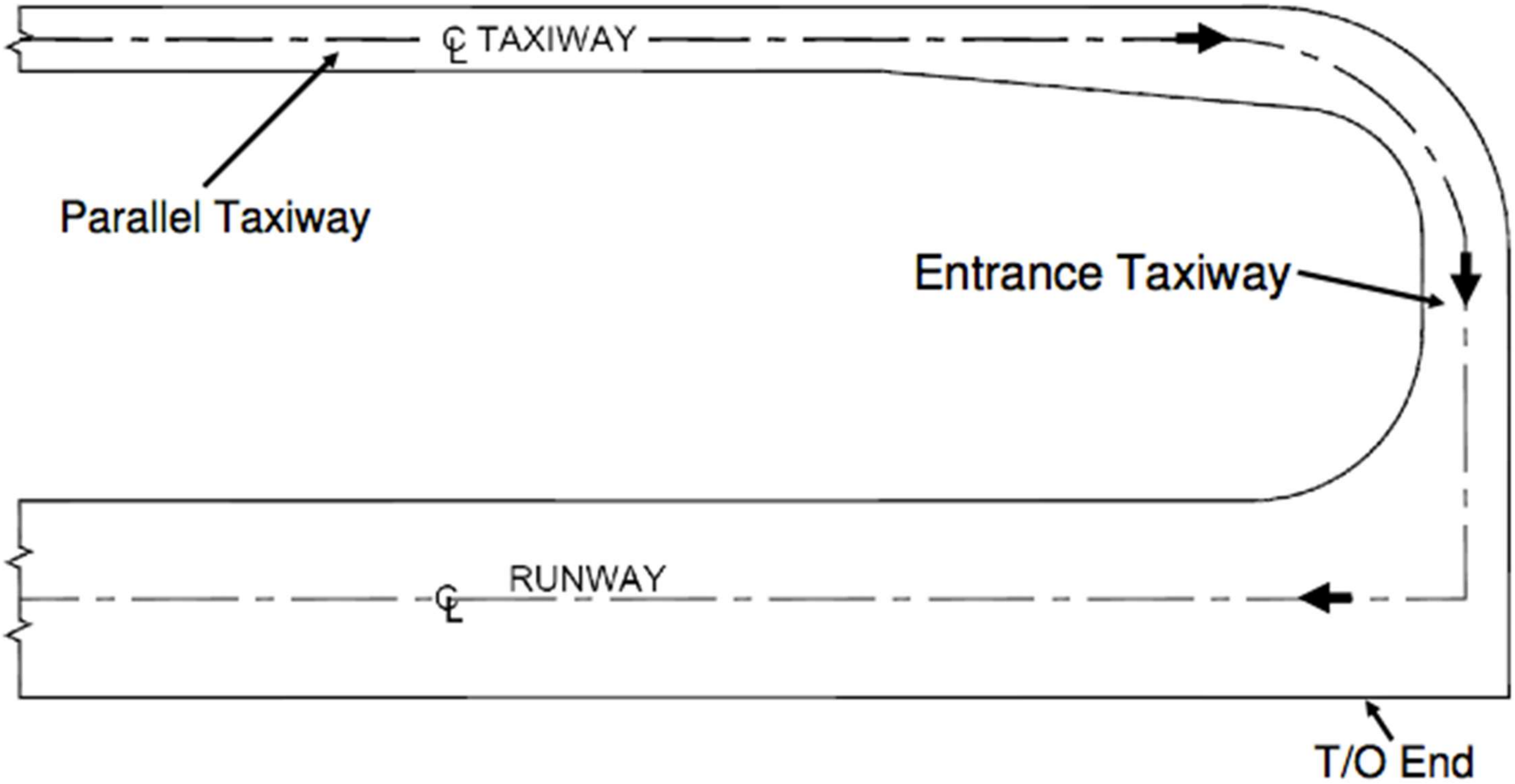
Typical High Speed Exit Taxiway



Entrance & Parallel Taxiways

- Entrance Taxiway:
  - Entrance taxiways provide access to the takeoff end of the runway for the departing aircrafts and it also serves as the final exit taxiway for landing aircrafts on a bidirectional runway. It is normally in the form of an “L” taxiway intersection with a right angle connection to the runway.
- Parallel Taxiway:
  - The taxiway running parallel to the runway connecting all the exit and entrance taxiways is called *parallel taxiway.*

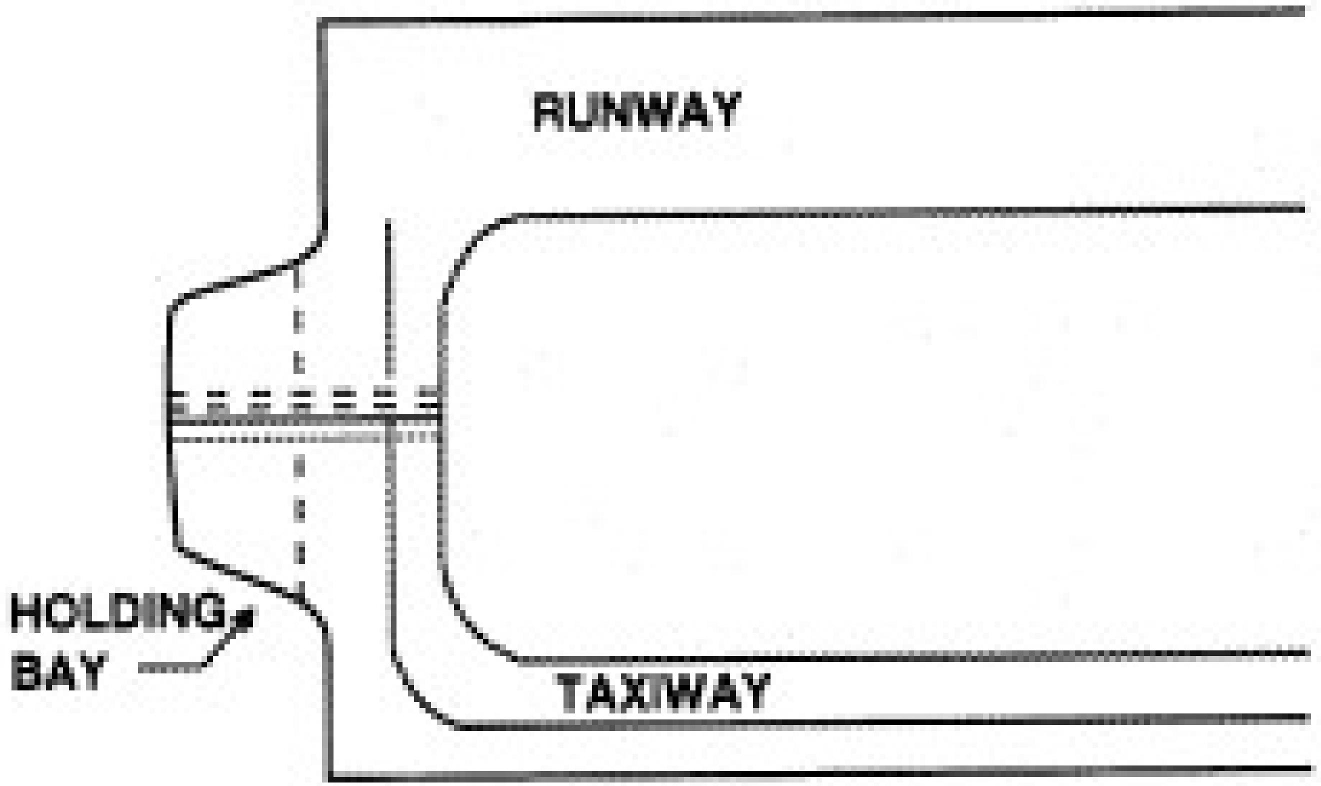
Entrance Taxiway



Source: FAA AC: 150/5300-13 (1989)

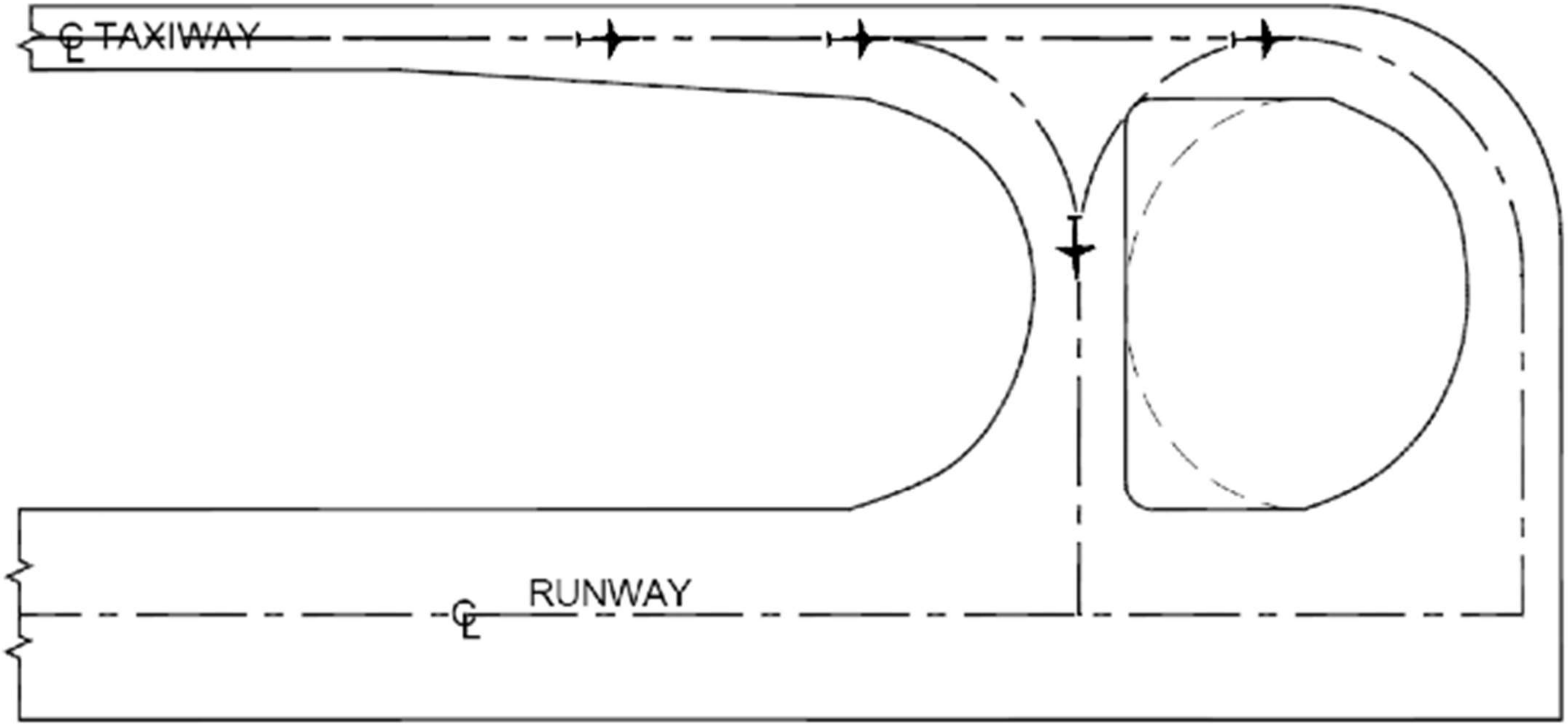
Bypass Taxiway

- As an alternative to holding bay a bypass taxiway parallel to the entrance taxiway leading to the runway end are generally provided.
- When a preceding aircraft is not ready for takeoff and blocks the entrance taxiway, other aircrafts in the queue can use the bypass taxiway.
- Bypass taxiways provide flexibility in runway use by permitting ground maneuvering of steady streams of departing airplanes.



Holding Bay

Bypass Taxiway



Source: FAA AC: 150/5300-13 (1989)

Thanks!

Week-(05)

MD Ehasan Kabir

Topic:

1. Introduction of Airport Configurations
2. Analysis of wind
3. Site Selection Approach

Introduction of
Airport Configurations

- A major determinant of airport capacity is the overall layout and design of the system
- Airport configuration is the most important factor and defined as the general arrangement of the various parts or components of the airport system

Airport Configuration

- Airport configuration is defined as the number and orientation of runways and the location of the terminal area relative to the runways.
  - Number of runways depends on air traffic volume.
  - Orientation of runways depends on the direction of wind, size and shape of the area and land use and airspace use restrictions in the vicinity of airport.
  - The terminal building should be located so as to provide easy and timely access to runways.

Analysis of Wind for Orienting Runways

- Runways are oriented in the direction of prevailing winds.
- The data on the parameters of wind, namely- intensity (speed), direction and duration are essential to determine the orientation of runways.
  - High intensity winds perpendicular to the direction of runway cause problems during landing and takeoff of aircrafts.
  - Smaller aircrafts are particularly affected by these crosswinds.

Factors affecting selection of site for Airport

- Availability of adequate area
- Accessibility
- Topography, soil condition and drainage
- Availability of construction materials
- Cost of development
- Cost of maintenance
- Traffic volume and type of traffic
- Cross-wind component
- Proximity of airways
- Safety factors
- Revenues

Factors Influencing Airport Size

- Performance characteristics and size of aircraft expected to use the airport.
- Anticipated volume of traffic.
- Meteorological conditions.
- Elevation of site.

Topic: Planning and Design of the Terminal Area

1. The Passenger Terminal System
2. The Terminal Planning Process
3. The Apron Gate System

The Passenger Terminal System

- The passenger terminal refers to a building which is mainly used for the passengers, airline staff, cargo and administrative management, control tower, weather bureau etc.
- Passenger terminals provide the first and last impressions for visitors to the airport.
- The terminals are the ‘front door’ to the Airport and serve as the public interface between the landside and airside elements.
- The main aim of the airport is to provide high quality terminal facilities that effectively handle the projected traffic flows and provide a quality experience for customers.

The Terminal Planning Process

- There are three components of Planning

1. Airside Terminal facilities planning
2. Terminal building facilities planning
3. Land side facilities planning

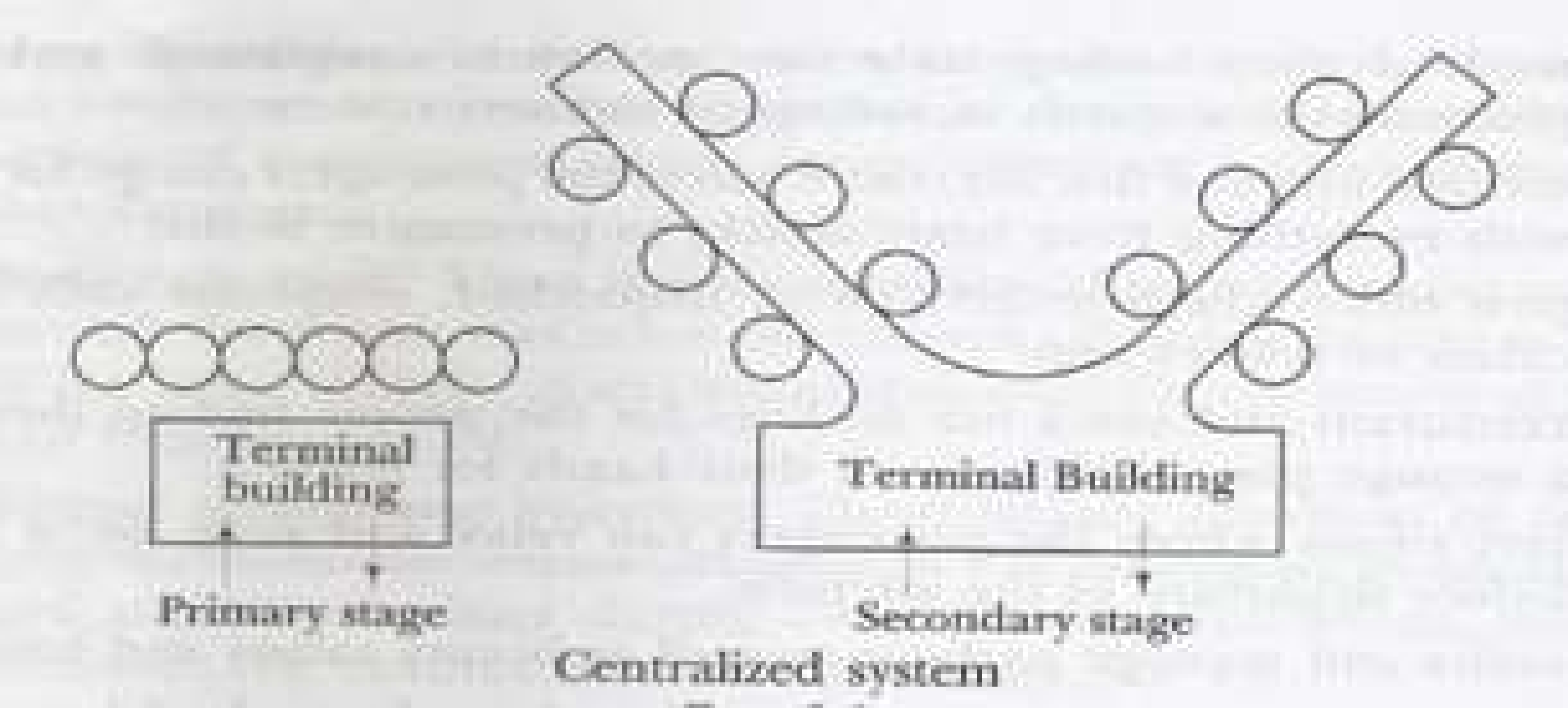
Terminal building facilities planning

- There are 3 concepts of planning the terminal building.

   1. Centralized system
   2. Decentralized system
   3. De-centralized – centralized system

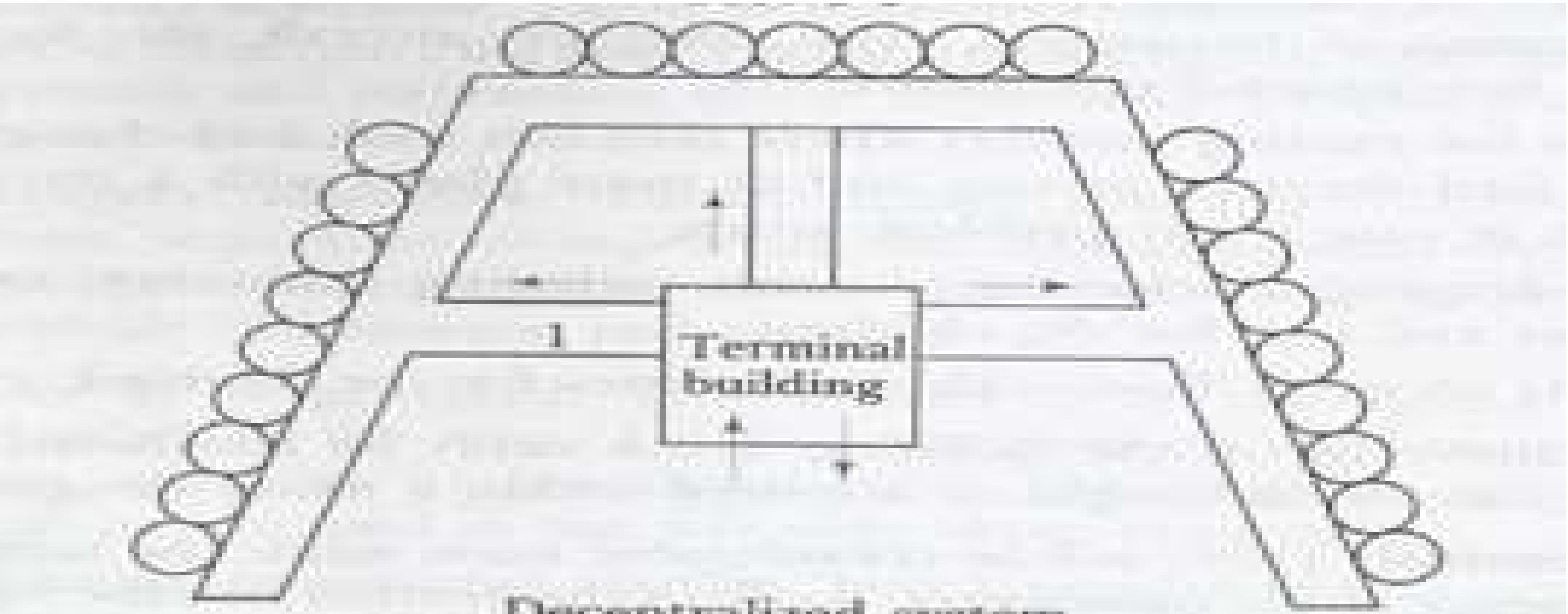
Centralized system

- In this system, all the passengers, baggage and cargo are routed through a central location and then passed on to the respective aircraft positions.
- It is economical
- This system is convenient when the aircraft parking area is within the walking distance of 180 m.



Decentralized system

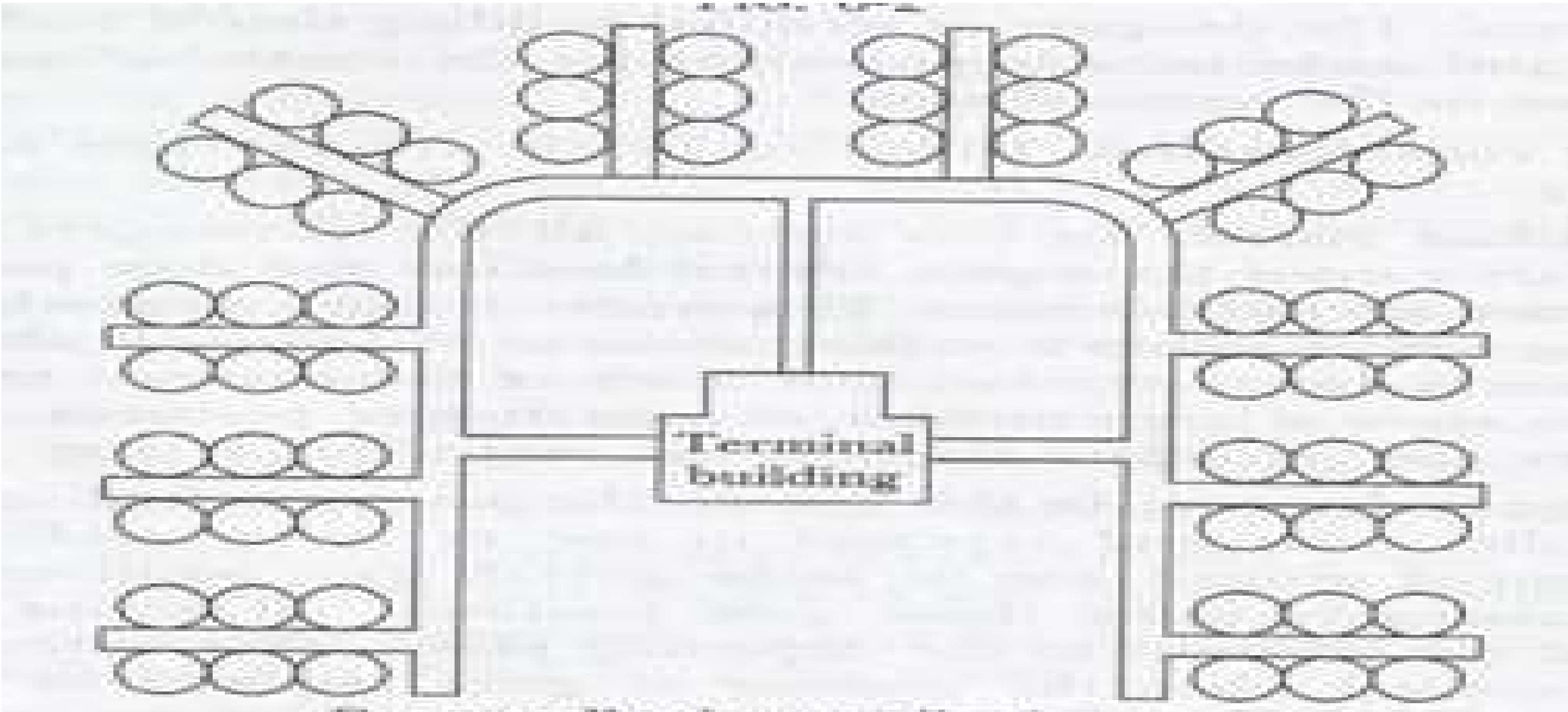
- In this system, the passenger facilities are arranged in smaller units and repeated in one or more buildings.
- Each unit is arranged around one or more aircraft gate positions
- All the airline functions are carried out adjacent to the departing plane.
- This system proves to be uneconomical when the number of gates required by the individual airliner are more than 6.



Decentralized system

De-centralized – centralized system

- It is a combination of the above two systems
- In this system, each individual airliner operation is centralized.
- This kind of system more suitable at major airports where the volume of air traffic is too high.



Decentralized-centralized system

The Apron-Gate System

- Apron

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

The size of the apron depends upon:

1. Gate position
2. Number of gates
3. Aircraft parking system

Gate position

- The term gate is used to denote an aircraft parking space adjacent to a terminal building and used by a single aircraft for the loading and unloading of the passengers, baggage and cargo.
- The size of the gate depends on

1. **Size of aircraft**

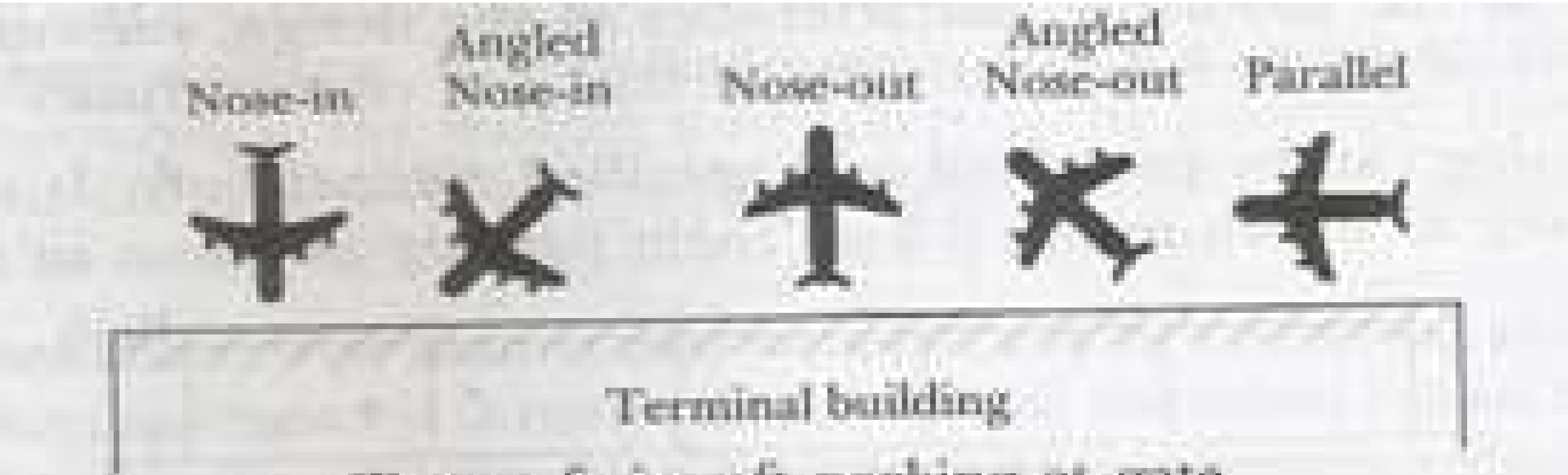
The size of aircraft to be accommodated determines the space required for parking as well as for maneuvering. It also determines the extent and size of the servicing equipment required to be provided to service the aircraft.

2. **Type of aircraft parking**

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

Type of Aircraft Parking

- There are 5 types of aircraft parkings.
  1. Nose-in-parking
  2. Angled nose-in parking
  3. Nose-out parking
  4. Angled nose-out parking
  5. Parallel parking.



Types of aircraft parking at gate

The Apron-Gate System

2. **The number of gates:**

- The number of gates is determined in such a way that a predetermined hourly flow of aircraft can be easily and conveniently accommodated.
- The number of gates required will depend on the following factors.

1. Estimated peak hour volume
2. Gate occupancy time
3. Gate capacity analysis
4. Gate utilization factor

Horonjeff proposed a deterministic model to compute the required number of gate positions, based on the design volume for arrivals and departures in aircraft per hour (C), mean gate occupancy time in hours (7), and a utilization factor (U).

The number of gate positions (G) was given by G= CT/U

The Apron-Gate System

3. Aircraft parking system:

- Depending on the horizontal terminal concept used, the aircraft can be grouped adjacent to the terminal building in a variety of ways.
- These groupings are referred to as parking systems and they can be classified in to the following 4 ways.
    1. Frontal or linear system
    2. Open- apron or transport system
    3. Pier or finger system
    4. Satellite System

Frontal or linear system

Open- apron or transport system

Pier or finger system

Satellite System

Thanks!

Week-(06)

MD Ehasan Kabir

Topic:

1. Air Traffic Control
2. Air Traffic Control Facilities
3. Air Safety and Regulation Issues

Air Traffic Control (ATC)

- **Air traffic control** (**ATC**) is a service provided by ground based controllers who direct the aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace.

Functions of Air Traffic Control

1. To prevent collisions and therefore safeguard life and property.
2. To organize and expedite the flow of traffic
3. To provide information and other support to pilots
4. ATC may play security or defensive role or is operated by the military in some countries.
5. To prevent collisions, ATC enforces traffic separation rules, which ensure each aircraft maintains a minimum amount of empty space around it at all times.
6. Modern aircrafts have a collision avoidance systems, which provide additional safety by warning pilots when other aircrafts get too close.
7. ATC is the nerve center of an airport.

Need of Air Traffic Control

- Air transportation must ensure safe, convenient and economic movement of aircraft from one airport to another airport. For this purpose, we need to control the air space.
- The aircraft flight from one airport to another airport is carried out in the following 4 phases.

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

Air Traffic Control Centre Functions

- The functions of air traffic control centre are classified into the following categories.

1. Airport traffic control
2. Airway traffic control
3. Airway communication
4. Non-airway traffic control (General)

Airport Traffic Control

1. To guide the aircraft, desiring to land or take off.
2. To control the taxiing of arriving and departing aircraft between apron and runway.
3. It is taken care of by Airport Traffic Control Tower (ATCT)

Airway Traffic Control

- This regulates the movement of aircraft along the air route with adequate lateral and vertical separation to avoid collision, especially when visibility is poor.
- Provide air traffic service to A/C operating on only IFR (not VFR) flight plans within controlled airspace.
- It is taken care of by Air Route Traffic Control Centre (ARTCC)

Berlin Air Route Traffic Control Center

Airway Communication

- Deals with conveying of airway and weather information to the pilot during the flight.
- This is normally done by ARTCC through Flight Service Stations (FSS) located at various locations along the airways.

General or Non-Airway Traffic Control

1. Its a serious problem when personal flying is done by a large number of people.
2. In such cases, the movement of aircraft, not flying along the airway, must be regulated to prevent interference to main air traffic.

Air Traffic Control Network

- The network for controlling the air traffic can be divided in to three parts.

1. Control within terminal area

    - taken care of by Air Traffic Control Tower (ATCT)

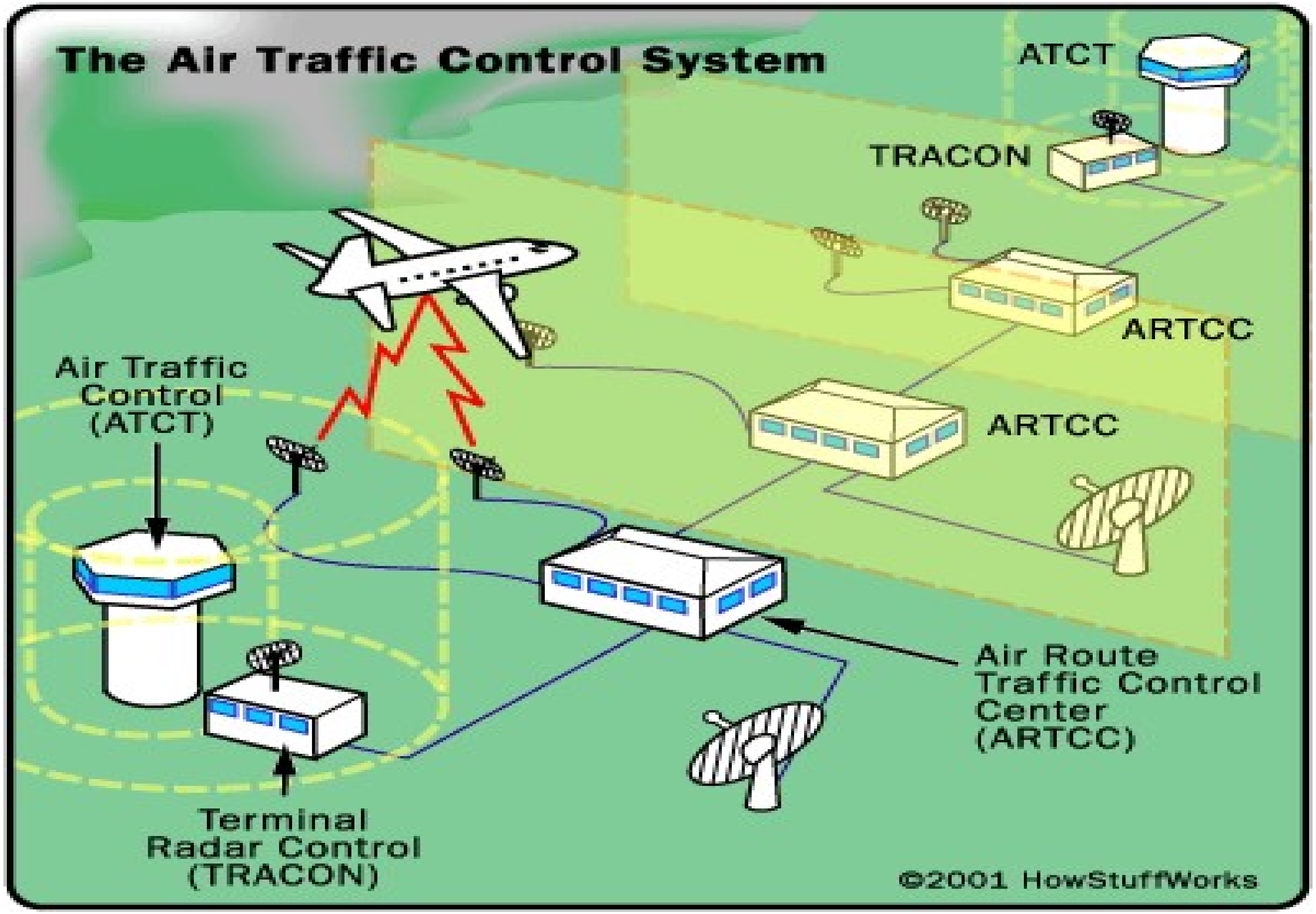
2. Control over airways

    - taken care of by Air Route Traffic Control Centre (ARTC)

3. Airway communication

    - taken care of by Flight Service Station (FSS)

Air Traffic Control Facilities



Air Traffic Control Room

Flight Operation Rules
(or Air Traffic Control Rules)

- Aircrafts operate under two basic types of flight rules

1. Visual Flight Rules (VFR Conditions)
2. Instrument Flight Rules (IFR Conditions)

1.Visual Flight Rules (VFR Conditions)

- If VFR conditions prevail, the air traffic control during the route is practically not required, since pilots can maintain desired separation by visual aids.

2. Instrument Flight Rules (IFR conditions)

- The IFR conditions exist, when the visibility is lower than the limits prescribed for flight under visual flight rules. For example during night times and bad weather conditions (cloudy or foggy).
- Rigid traffic control has to be exercised by ATC under IFR conditions.

- The pilot, prior to his departure, prepares a flight plan which include

1. aircraft destination
2. air route to be followed
3. the desired altitude
4. estimated time for departure

- If the flight plan is approved, no change is allowed without prior approval of the Air traffic control centre.

Air Traffic Control Aids

- The following air traffic control aids are always available to the pilot during the flight

1. Enroute aids or airway aids
2. Landing aids
3. Visual aids

Enroute Aids

The following aids are available to the pilot during his flight from one airport to another

1. Air Route Surveillance Radar (ARSR)
2. Air to ground communication
3. Airway Beacon
4. Direction Finder
   a) Automatic Direction Finder (ADF)
   b) Radio Direction Finder (RDF)
5. Distance Measuring Equipment (DME)
6. Low/Medium Frequency ratio range (LF/MF)
7. Marker Beacon
8. Tactical Air Navigation (TACAN)
9. Very high frequency Omni-directional Range (VOR)

Landing Aids

- The following aids are available to any aircraft while landing

1. Airport Surface Detection Equipment (ASDE)
2. Airport Surveillance Radar (ASR)
3. Instrument Landing System (ILS)
4. Precision Approach Radar (PAR) or Ground Approach Control (GAC)
5. Approach lights

Enroute Aids:
Air Route Surveillance Radar (ASR)

- The long-range radars are installed along the airways to keep a watch on the aircraft.
- The controller gets a picture of each aircraft on the radar screen and he/she is able to decide the exact position of the aircraft.
- The effective range of radar is about 200 km.

Enroute Aids:
Air to Ground Communication

- The flight instructions and other relevant data will be conveyed to pilot from the ground along the length of the airway through FSS and ARTCC.

Enroute Aids:
Airway Beacon

- In the past, the airway beacons were placed at a distance of about 40 km along the airway from one airport to another airport to provide guidance to the pilot.
- They are not existing now. They exist only certain key locations like the hill peaks.

Enroute Aids:
Direction Finder

There are two types of direction finders.

a) Automatic Direction Finder (ADF)

Automatic Direction Finder (ADF) is the modern sophisticated equipment which keeps the antenna pointed towards the point of transmission and it requires no adjustment.

b) Radio Direction Finder (RDF)

The Radio Direction Finder (RDF) is to be rotated by the pilot to find out his direction with respect to the transmittier.

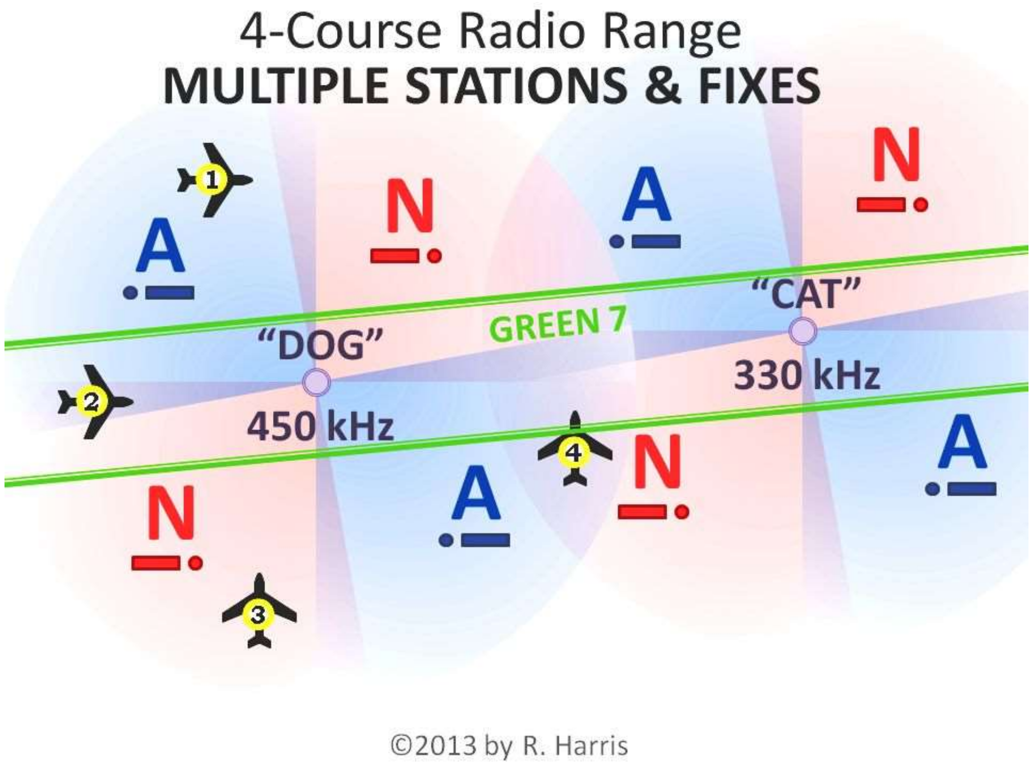
Enroute Aids:
Distance Measuring Equipment (DME)

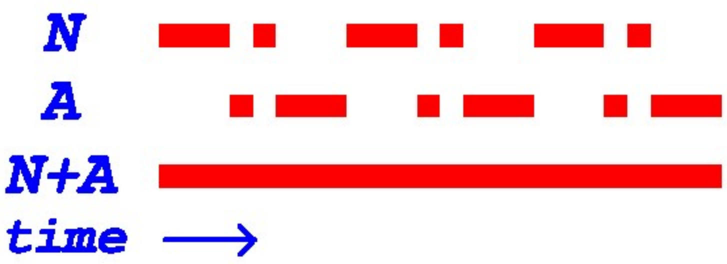
- The equipment known as the Distance Measuring Equipment (DME) has been installed at nearly all the VOR stations.
- It indicates to the pilot the air distance between the aircraft and a particular VOR station.
- The pilot is able to gauge his exact position by knowing his bearing with respect to the airway.

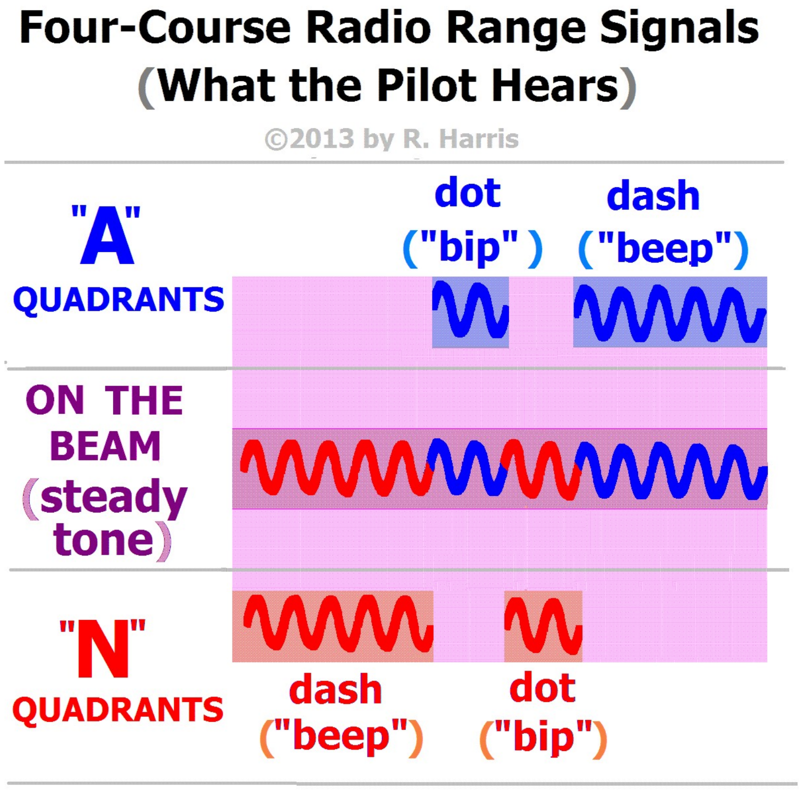
Enroute Aids:

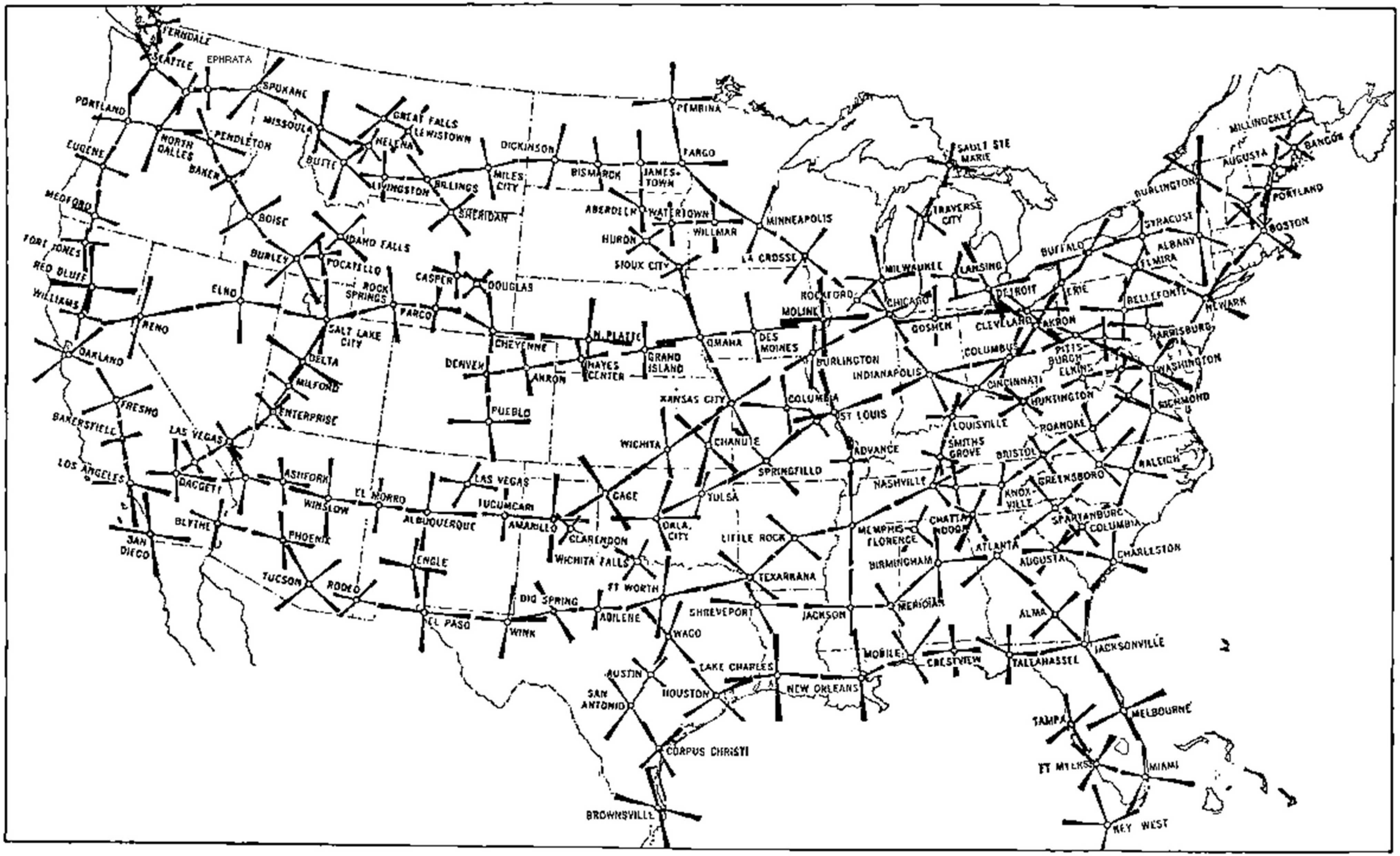
Low/Medium Frequency ratio range (LF/MF)

- It was invented during early1930s.
- The four course radio range sends out 4 radio beams along 4 directions.
- This facility may be located near an airport.
- If a pilot is able to pick up a steady tone, it indicates the correctness of the air route.
- If pilot is not on the correct route, he will hear a dot-dash or dash-dot signal and he can adjust his position accordingly.
- There will be difficulty of static interference.
- The reception of radio signal will be almost absent during thunder storm.


4-Course Radio Range
MULTIPLE STATIONS & FIXES
A
N
A
N
"DOG"
GREEN 7
"CAT"
450 kHz
330 kHz
N
A
N
A
©2013 by R. Harris


N
A
N+A
time


Four-Course Radio Range Signals
(What the Pilot Hears)
©2013 by R. Harris
"A"
QUADRANTS
dot
("bip")
dash
("beep")
ON THE
BEAM
(steady
tone)
"N"
QUADRANTS
dash
("beep")
dot
("bip")



The radio range system of the Civil Aeronautics Administration.

Enroute Aids:

Marker Beacon

The small radio transmitters known as the marker beacons are helpful to the pilot for determining his position on a given airway.

They send coded radio signals which the pilot is able to identify.

There is a cone of silence just above the tower of radio range station.

As the aircraft enters the cone, the signals fade out and remain blank until the aircraft is in the cone area.

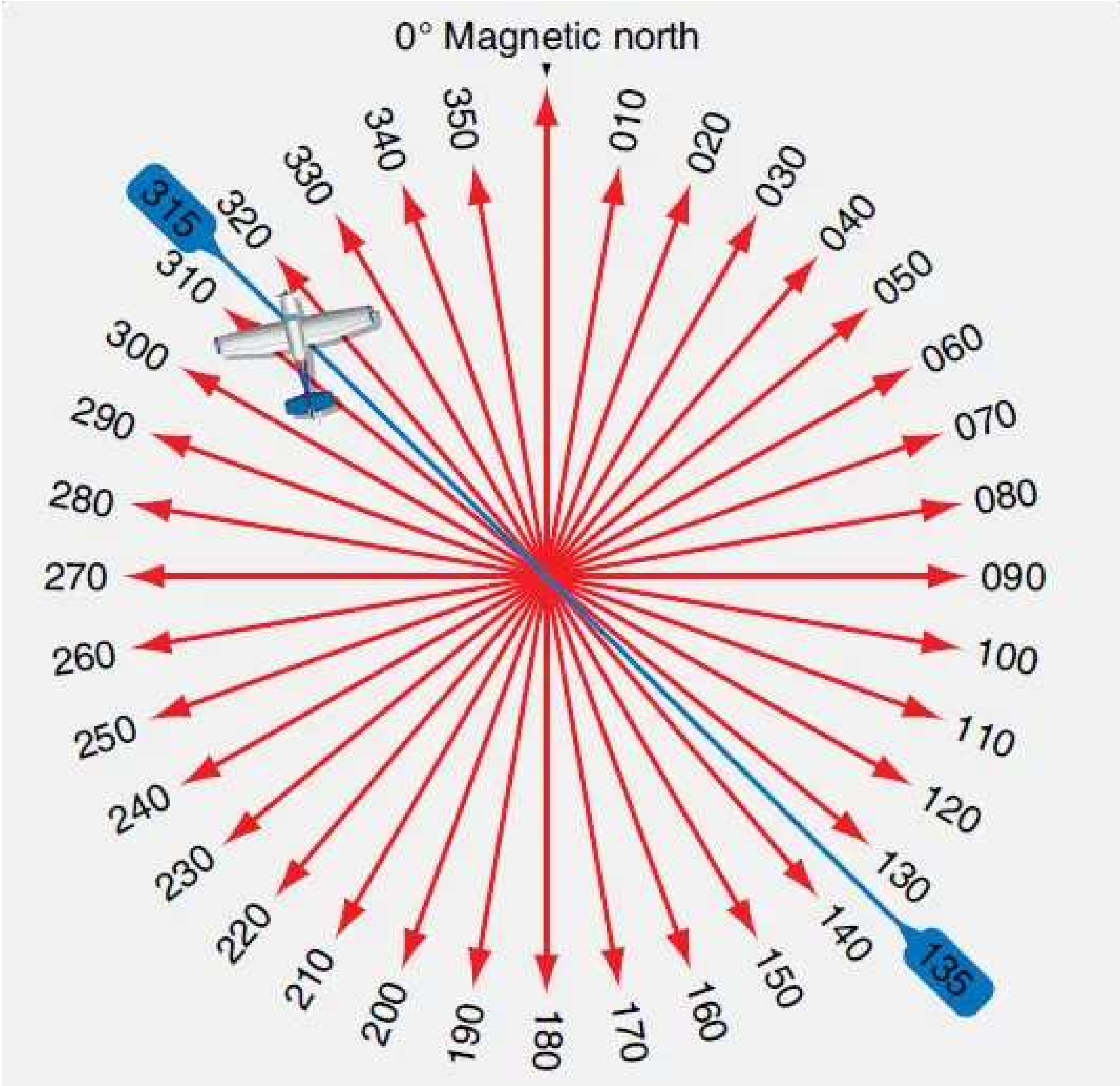
Enroute Aids:
Tactical Air Navigation (TACAN)

- It measures the azimuth and distance.
- It is operated in the ultra-high frequency band.

Enroute Aids:

Very high frequency Omni-directional Range (VOR)

- The most common ground system from which the bearings can be known is the VOR.
- The VOR stations sends out signals in all directions with 1^o interval. There will be 360 routes. 0^o refers to Magnetic north
- Each signal can be considered of a course or route referred to as a radial that can be followed by an aircraft.
- The VOR receiver in the cockpit has a dial for tuning in the desired VOR frequency.
- The pilots can select the VOR radial or route they wish to follow to the VOR station.
- The VOR stations are usually located on a small square building standing on an unobstructed hill top or in the open grounds.
- The very high frequencies are free from static interference.


0° Magnetic north
010
020
030
040
050
060
070
080
090
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
315
135

Landing Aids:
Airport Surface Detection Equipment (ASDE)

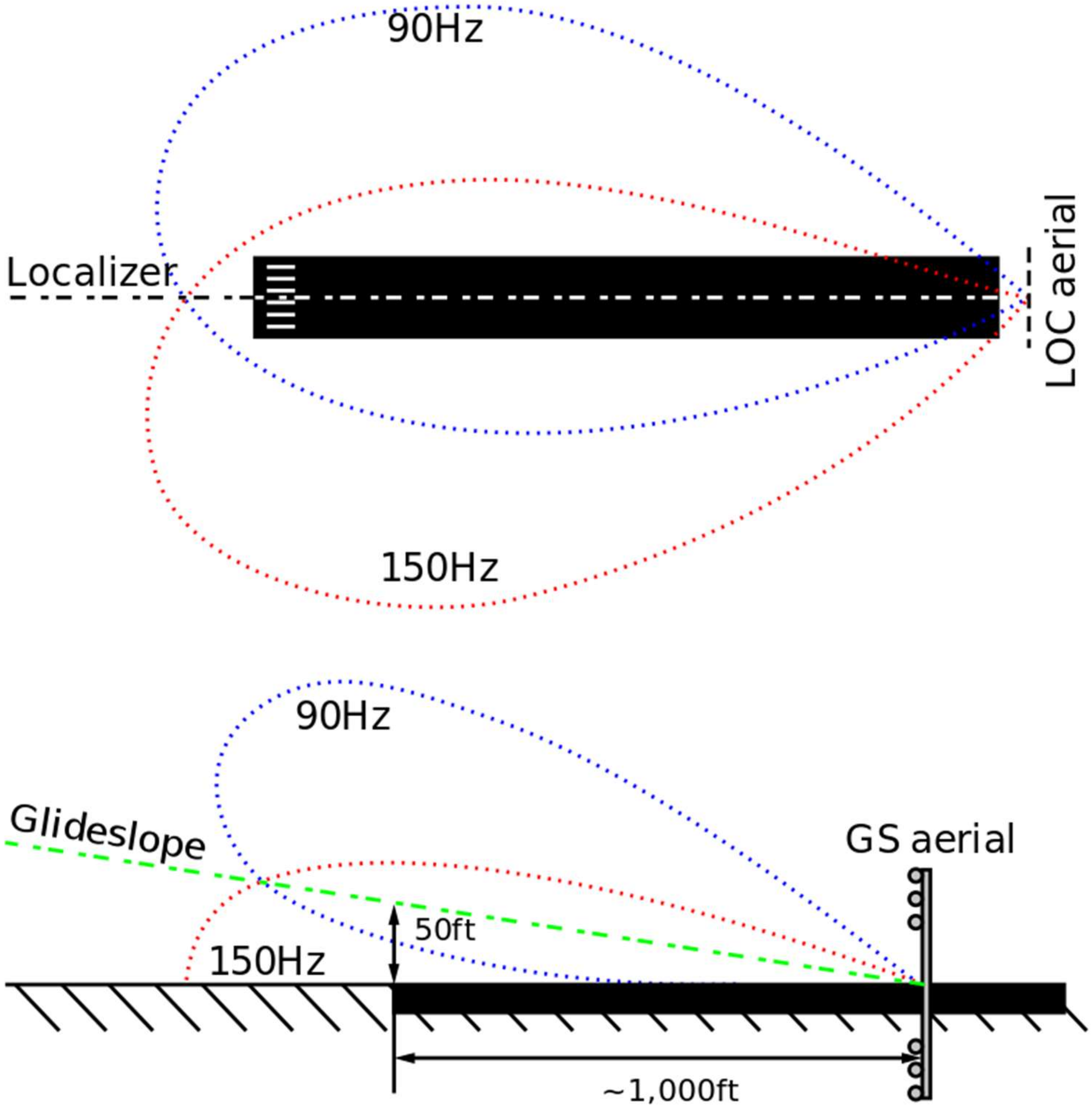
- During poor visibility conditions, the controllers experience difficulty in regulating taxiing aircraft because they are unable to see them.
- The ASDE gives pictorial display of runways, taxiways and terminal area along with the position of the aircraft.

Landing Aids:
Airport Surveillance Radar (ASR)

- Airport Surveillance Radar (ASR) is an instrument which provides to the control tower operator an overall picture of what is going on with in airspace surrounding the terminal.
- The ASR rotates through 360^o and it has a range of 50 to 100 km.
- The information is received on a screen in the control tower.
- The relative horizontal positions of the aircraft are shown as blips.
- The blips of a moving aircraft leave a luminous trail or mark showing their direction and speed.

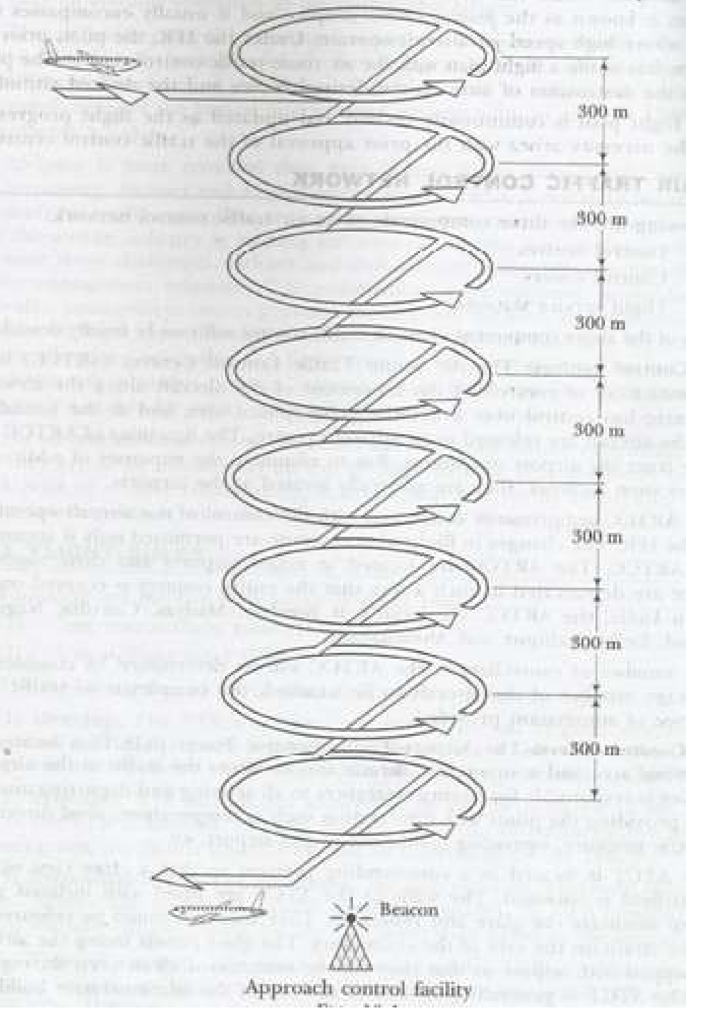
Landing Aids:
Instrument Landing System (ILS)

- It consists of telecommunication aids to the pilot to enable him to approach the runway and make a successful landing under conditions of poor visibility even when no ground reference data is visible.
- The ILS consists of the following two transmitted signals which combine to form an invisible path along which the aircraft can approach.
  1. Glide Slope Antenna
  2. Localiser Antenna

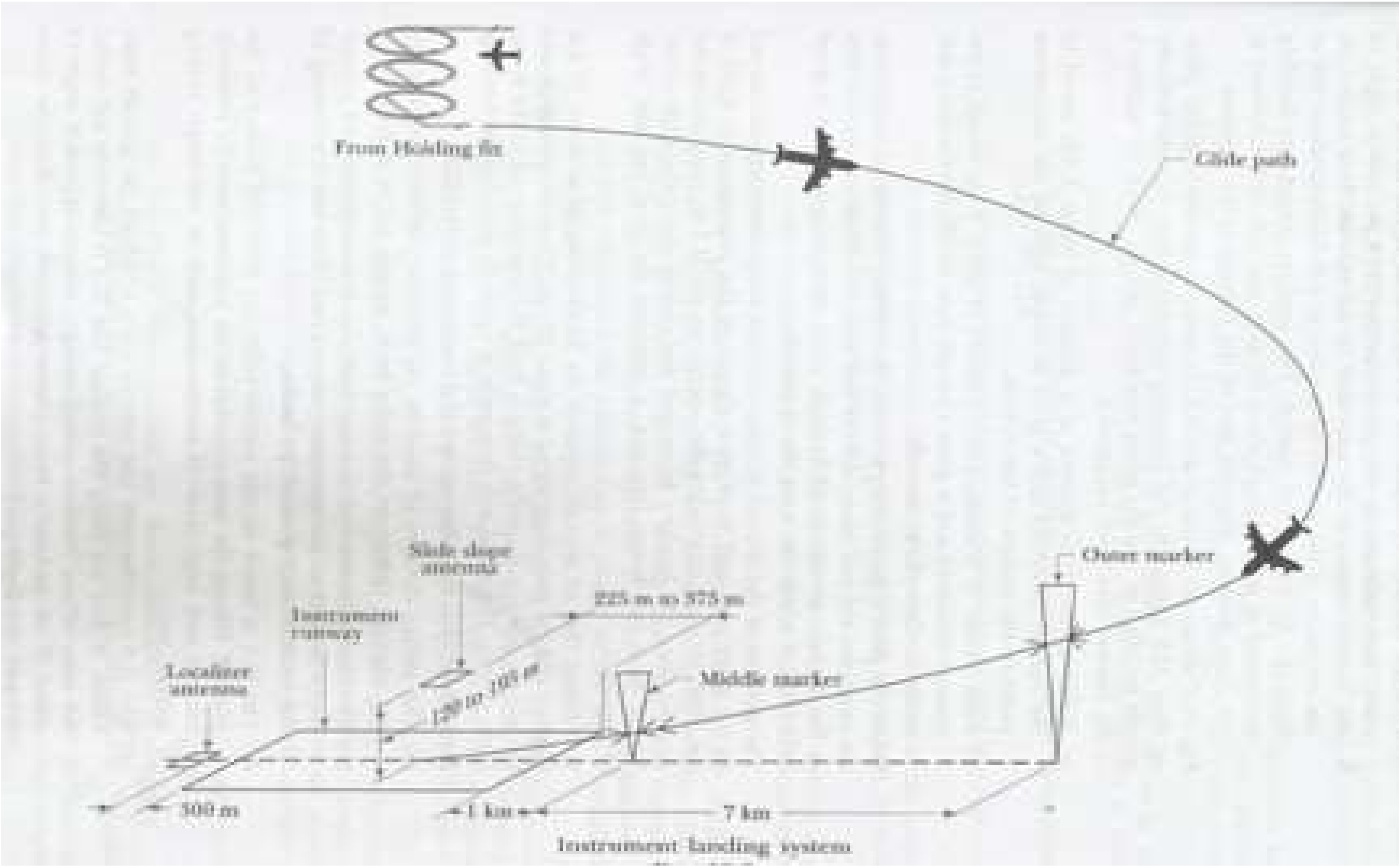

90Hz
Localizer
LOC aerial
150Hz
90Hz
Glideslope
GS aerial
50ft
150Hz
~1,000ft

Holding Fix

If the traffic is heavy on the runway, then the aircrafts are detained at this place known as **“Holding Fix”** and they are required to keep moving with a vertical separation of 300 m. They are released one by one by the ARTC (or ATCT with approach control facilities).



Instrument Landing System



Landing Aids:
Precision Approach Radar (PAR)

- The Precision Approach Radar (PAR) or Ground Control Approach (GCA) serves the same purpose as an ILS except that the information is passed to the pilot through the hearing aid.
- It contains a mobile unit.

Landing Aids:

Approach lights

- The pilot has to change from the instrument to visual conditions as he approaches the most critical point of the runway threshold.
- The time available for the pilot is hardly a few seconds in which he has to make the transition and complete landing.
- To aid in making this transition with confidence, the lights are installed on the approach to the runway as well as on the runway themselves.
- These are known as Approach Lighting System (ALS)

GPS Air Traffic Control or Next Generation Air Transportation System

- It is originally designed to assist soldiers in military vehicles/planes
- The Next Generation Air Transportation System (NextGen) is a new National Airspace System due for implementation across the United States in stages between 2012 and 2025.
- NextGen proposes to transform America's air traffic control system from a ground-based system to a satellite-based system.
- GPS technology will be used to shorten routes, save time and fuel, reduce traffic delays, increase capacity, and permit controllers to monitor and manage aircraft with greater safety margins. Planes will be able to fly closer together, take more direct routes and avoid delays caused by airport "stacking" as planes wait for an open runway

Free Flight Air Traffic Control

- Free Flight is a new concept.
- True free flight eliminates the need for Air Traffic Control (ATC) operators by giving the responsibility to the pilot in control.
- This gives the pilot the ability to change trajectory in mid flight.
- With the aid of computer systems and/or ATC, pilots will be able to make more flight path decisions independently.

Airways

- An **airway** is a legally defined corridor that connects one specified location to another at a specified altitude, along which an aircraft that meets the requirements of the airway may be flown. Airways are defined with segments within a specific altitude block, corridor width, and between fixed geographic coordinates for satellite navigation systems, or between ground-based radio transmitter navigational aids (navaids) (such as VORs) or the intersection of specific radials of two navaids.
- There are two types of airways

1. Low Altitude routes or Victor routes
2. **High Altitude routes or Jet routes**

Low Altitude routes or Victor routes

- **Low Altitude routes** Serve primarily smaller piston engine, propeller driven airplanes on shorter routes and at lower altitudes. Airways start at 1,200 feet above ground level (AGL) and extend upward to an altitude of 17,500 feet mean sea level (MSL).

- Low Altitude airways are called "Victor" (V) airways, because they run primarily between VORs, and the phonetic alphabet term for "V" is Victor. Airways can be found on enroute low altitude charts and have names like V240 or V37.

High Altitude Routes or Jet Routes

- **High Altitude routes** actually called jet routes primarily serve airliners, jets, turboprops, and turbocharged piston aircraft operating over longer distances at altitudes of 18,000 feet MSL or higher. Jet routes start at 18,000 feet mean sea level (MSL) and extend upward to FL450 MSL. Jet routes can be found on enroute high altitude charts and have names like J42 or J121.

Thanks!

Week-(07)

MD Ehasan Kabir

Visual Aids

When approaching the airport, the pilots require the help of visual aids for carrying out landing operation.

There are two important types of Visual Aids. They are

1. Airport Markings
2. Airport Lighting

Airport Markings

The runways, taxiways and other allied components of the airport should be properly marked so that they can be easily interpreted by the pilot who is negotiating at a considerable height.

Types of Markings

There are 6 types of Airport Markings

1. Runway Marking
2. Taxiway Marking
3. Shoulder Marking
4. Apron Markings
5. Landing Direction Indicator
6. Wind Direction Indicator

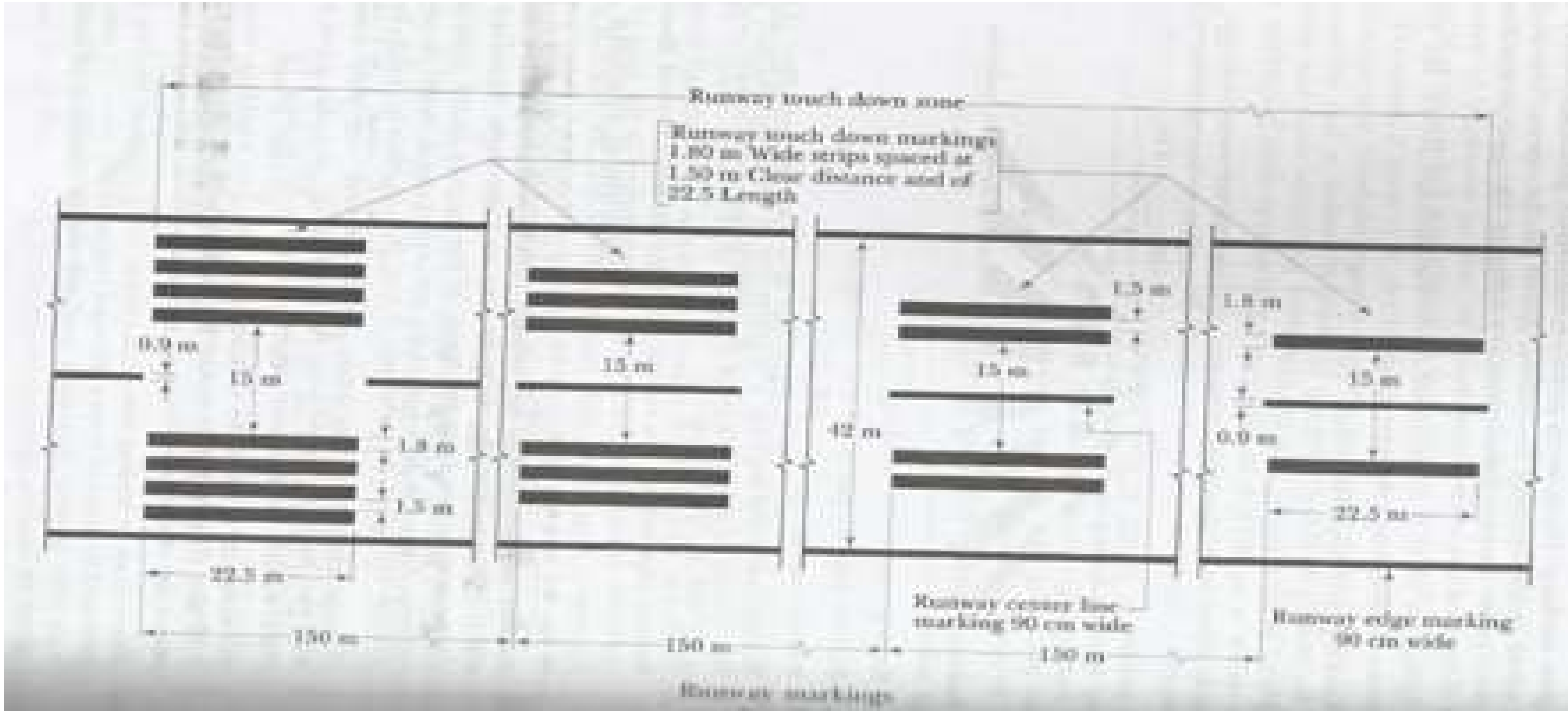
Runway Markings

- Following markings are made on the runways

1. Runway centre-line marking
2. Runway edge stripes
3. Touch down zone marking
4. Threshold marking
5. Displaced threshold marking
6. Runway numbering
7. Two or more parallel runways

Runway centre-line marking

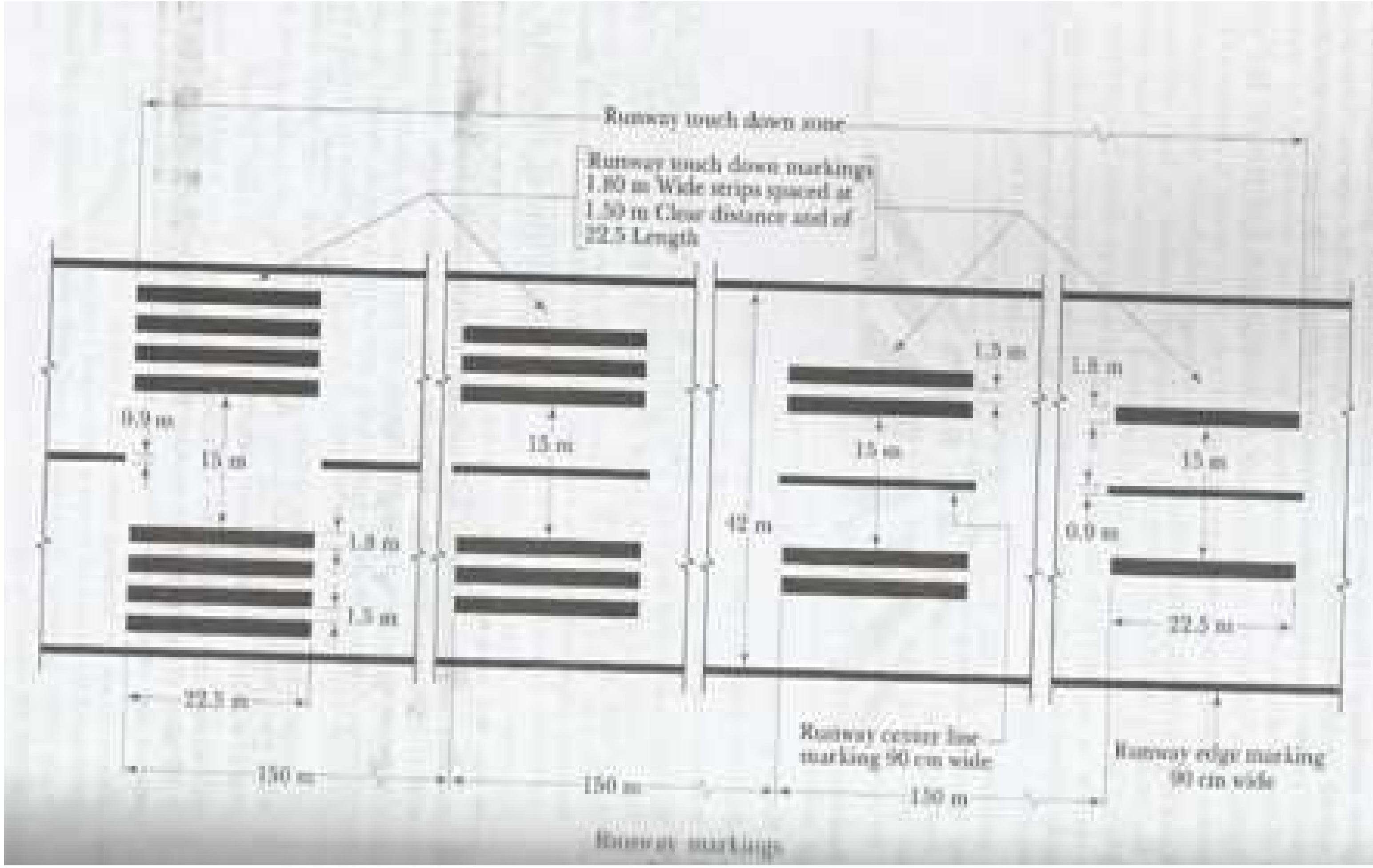
- It is represented by a broken line along the entire length as shown in figure.
- Its width is 90 cm.



Runway edge stripes

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

Runway Markings



Touch Down Zone Marking

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

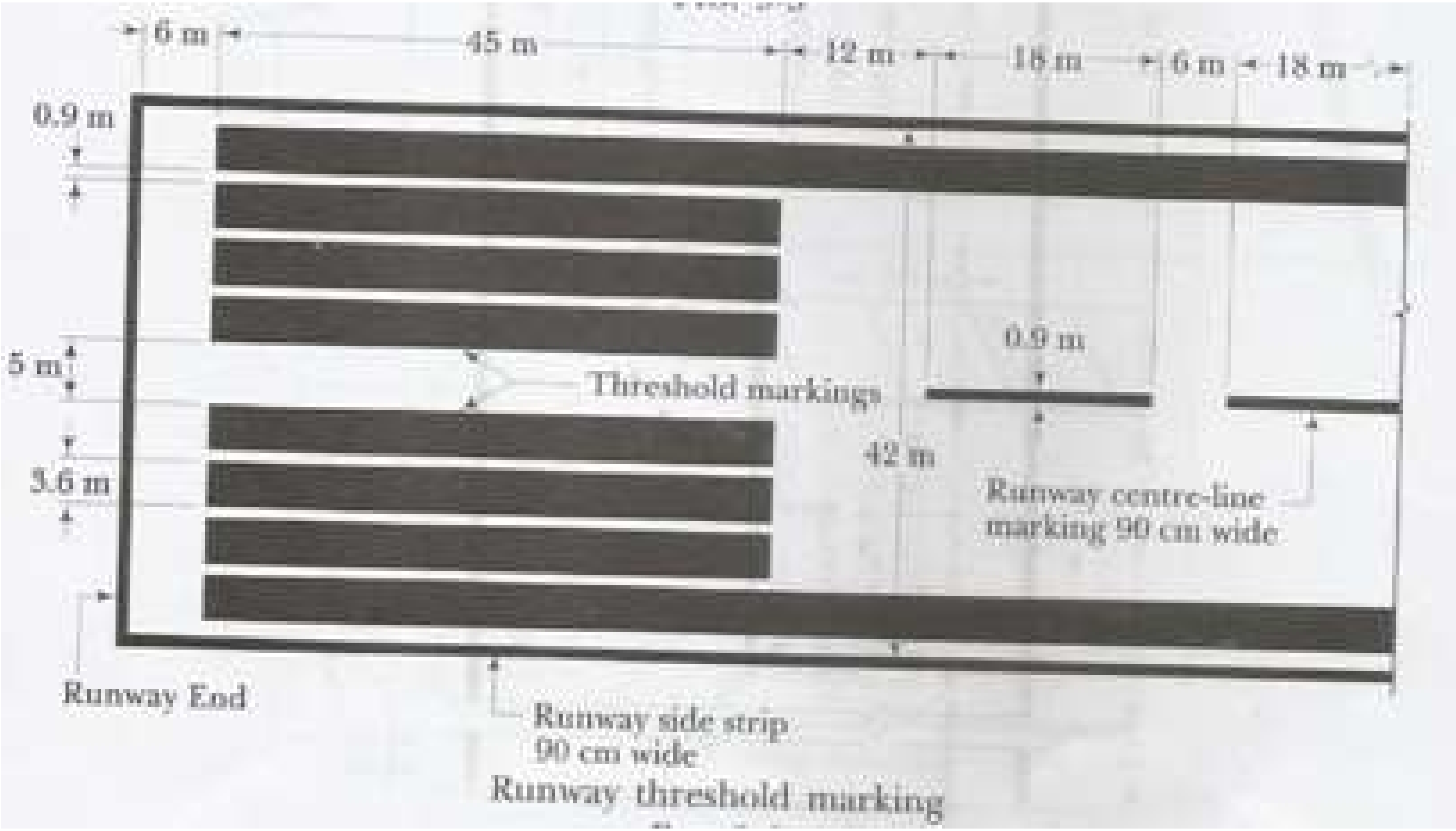
Perspective view of a Runway

Threshold Marking

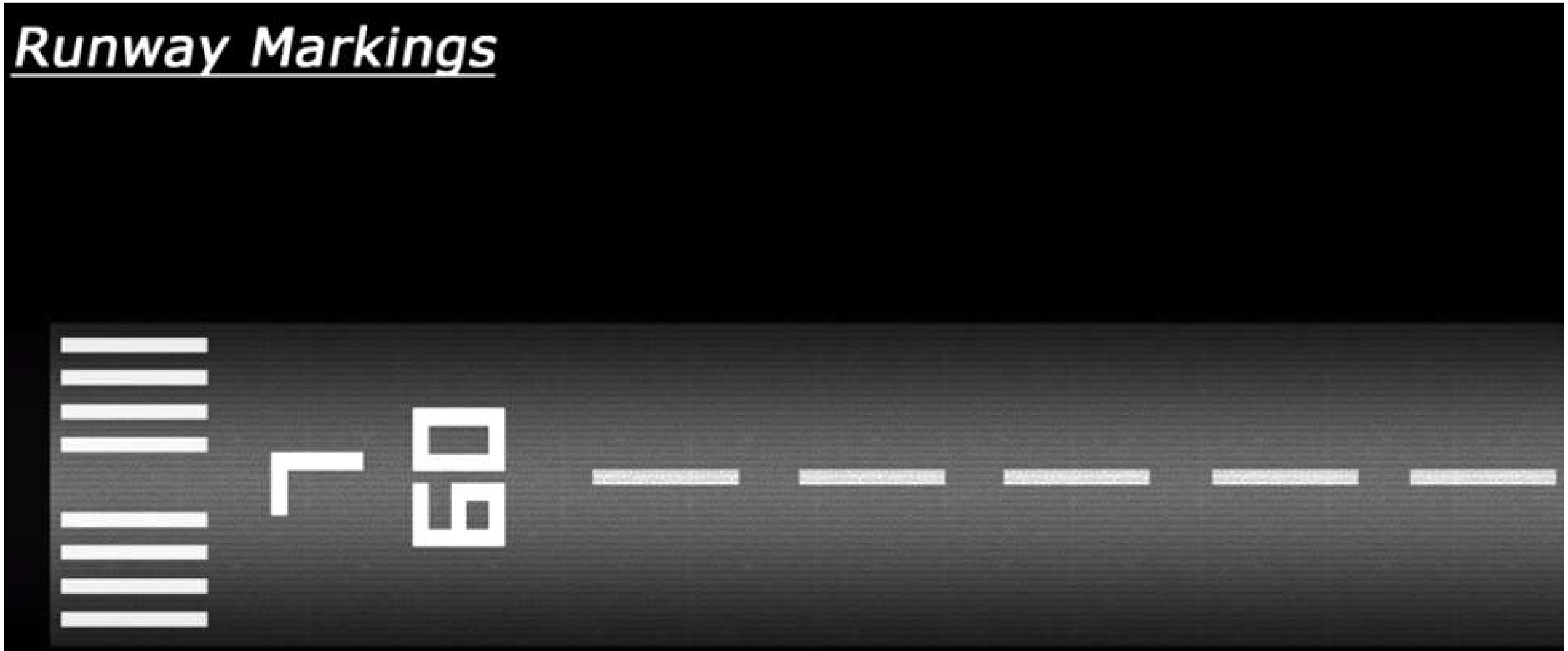
- The runway threshold is indicated by a series of parallel lines starting from a distance of 6 m from the runway end.

- The threshold markings are in the form of stripes 3.6 m wide spaced at 0.9 m clear and placed symmetrically on either side of the runway centre-line.

Runway Threshold Marking



Runway Threshold Marking



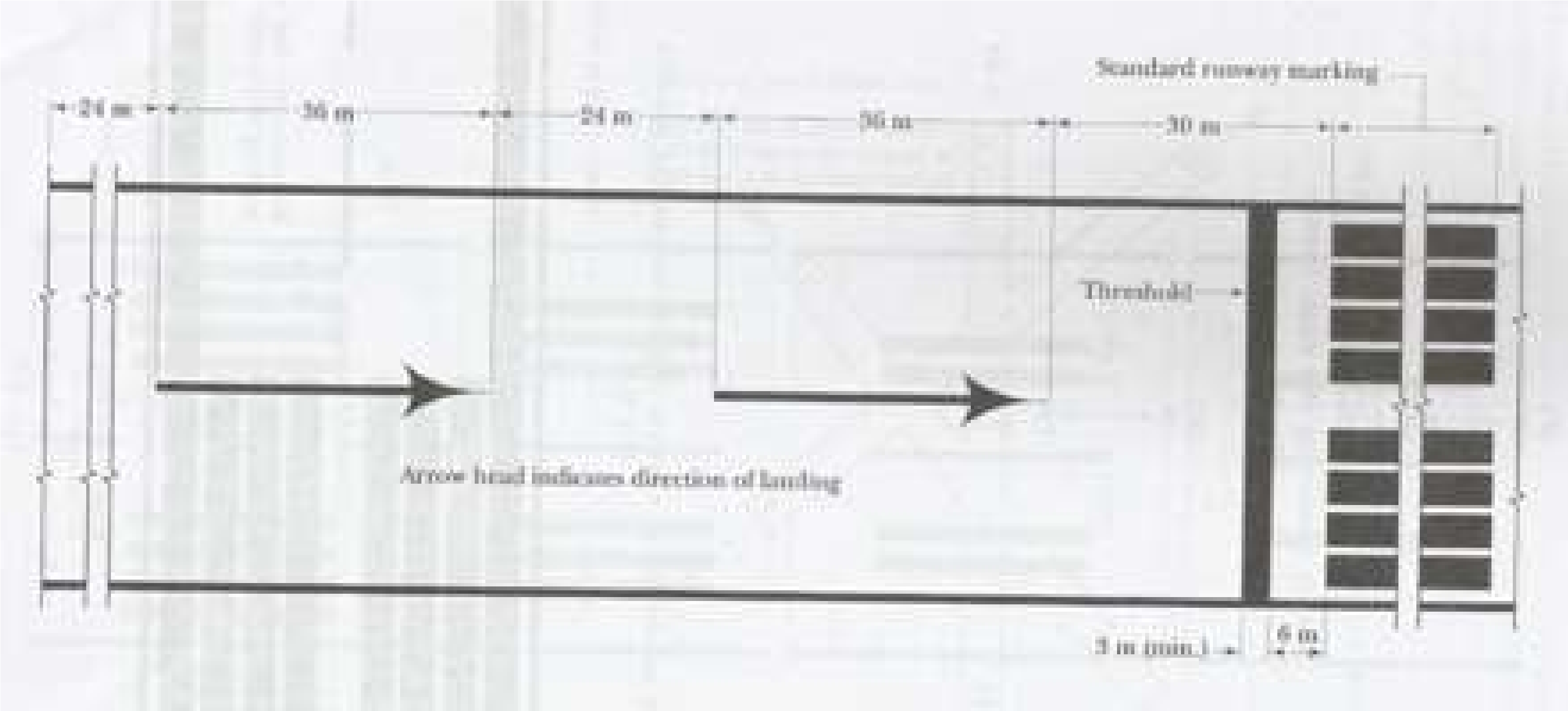
Bars		Width
4	-	60ft (18m)
6	-	75ft (23m)
8	-	100ft (30m)
12	-	150ft (45m)
16	-	200ft (60m)

Displaced Threshold Marking

- At some airports, it is desirable to displace the runway threshold on a permanent basis.

- A displaced threshold is one which has been moved a certain distance from the end of the runway.

Displaced Threshold Marking

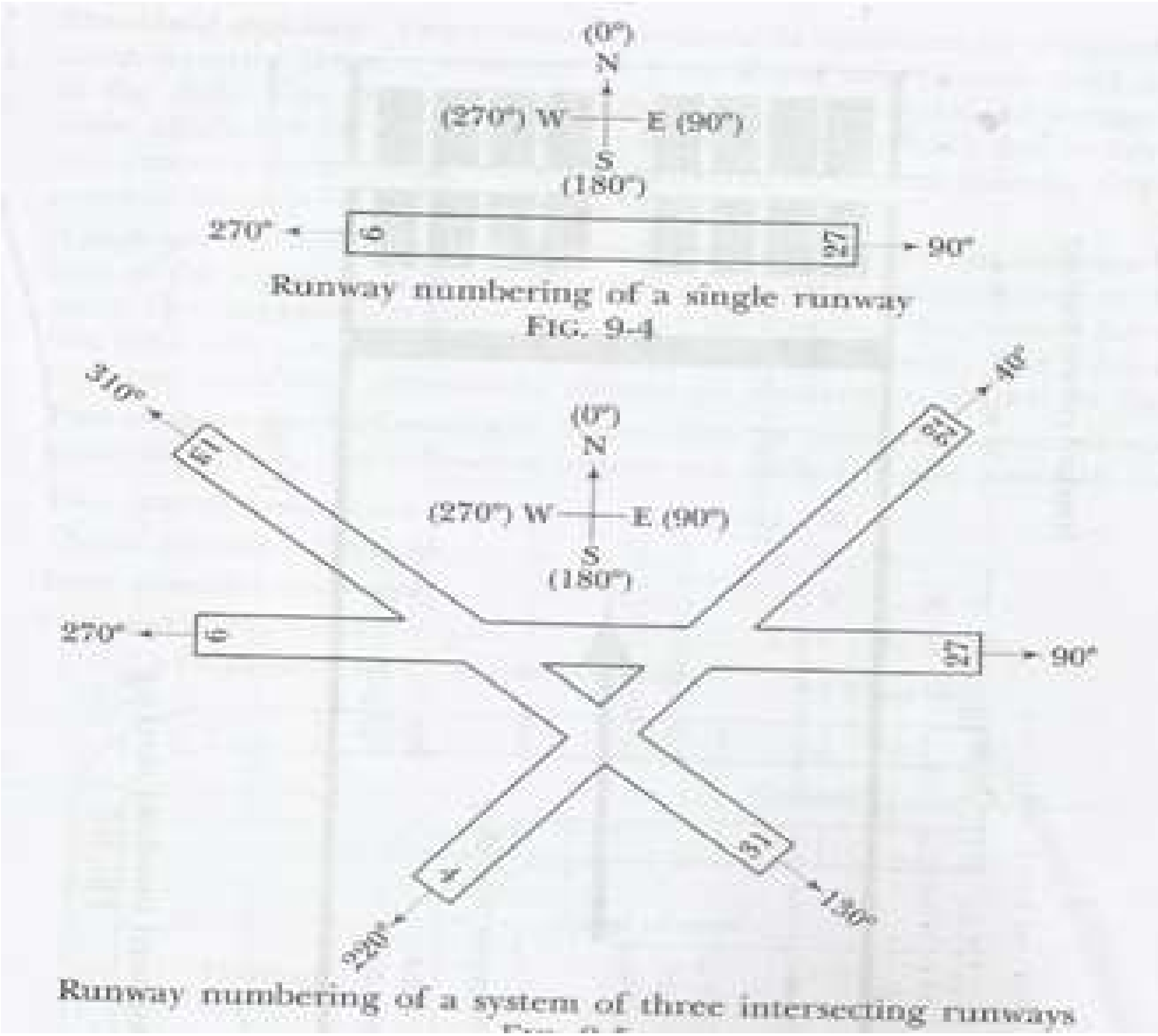


Displaced threshold marking

Runway numbering

- Runways are named by a number between 01 and 36, which is generally the magnetic azimuth of the runway's heading in decadegrees.
- A runway numbered 09 points east (90°), runway 18 is south (180°), runway 27 points west (270°) and runway 36 points to the north (360° rather than 0°).

Runway Numbering



Runway numbering of a single runway
FIG. 9-4

Runway numbering of a system of three intersecting runways

Two or More Parallel Runways

- When there are more than one runway in the same direction, the following letters are added to the azimuth numbers.

Two parallel runways - L, R

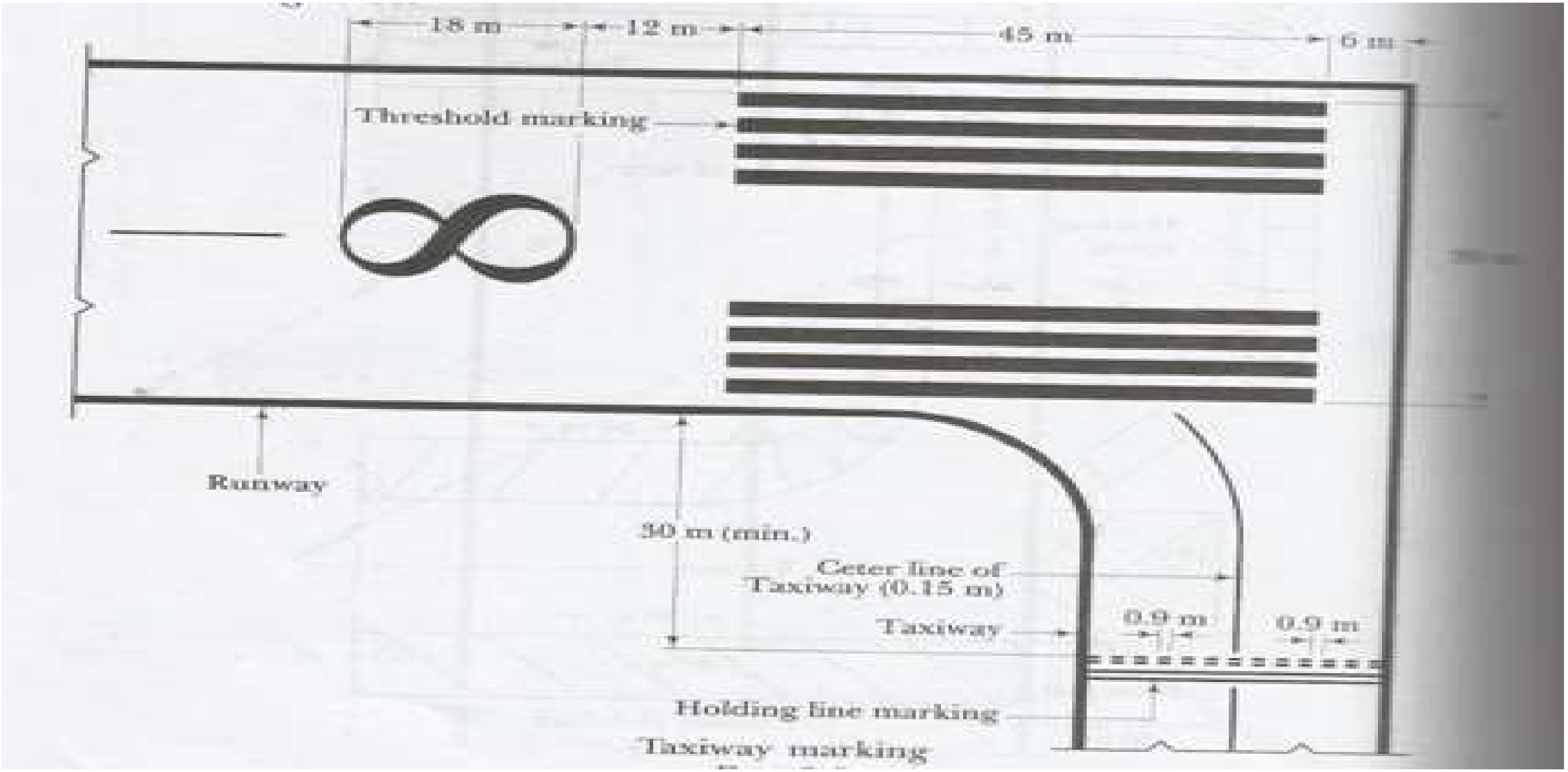
Three parallel runways - L, C, R

Taxiway Marking

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

Taxiway Marking

- At the intersections of the taxiways with the runway ends, the centre line of the taxiway is terminated at the edge of the runway.



Taxiway Marking

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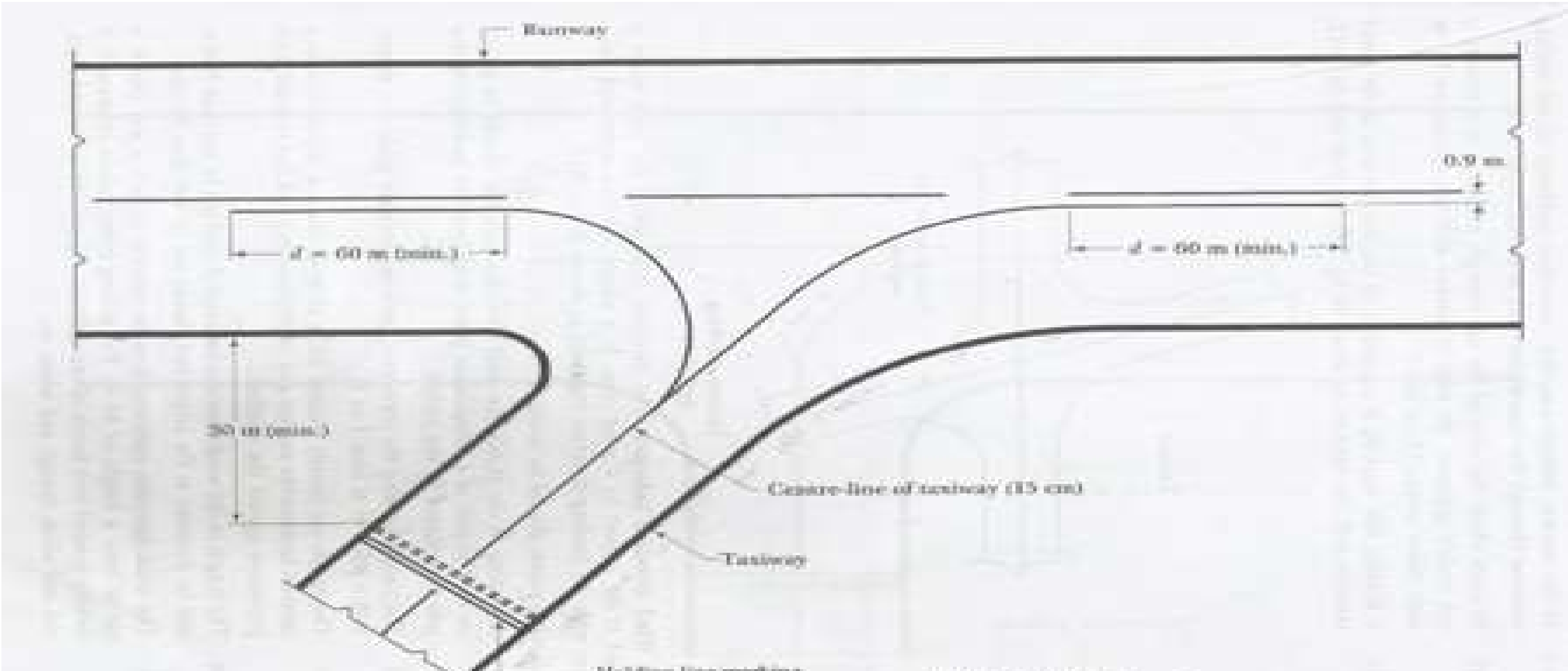
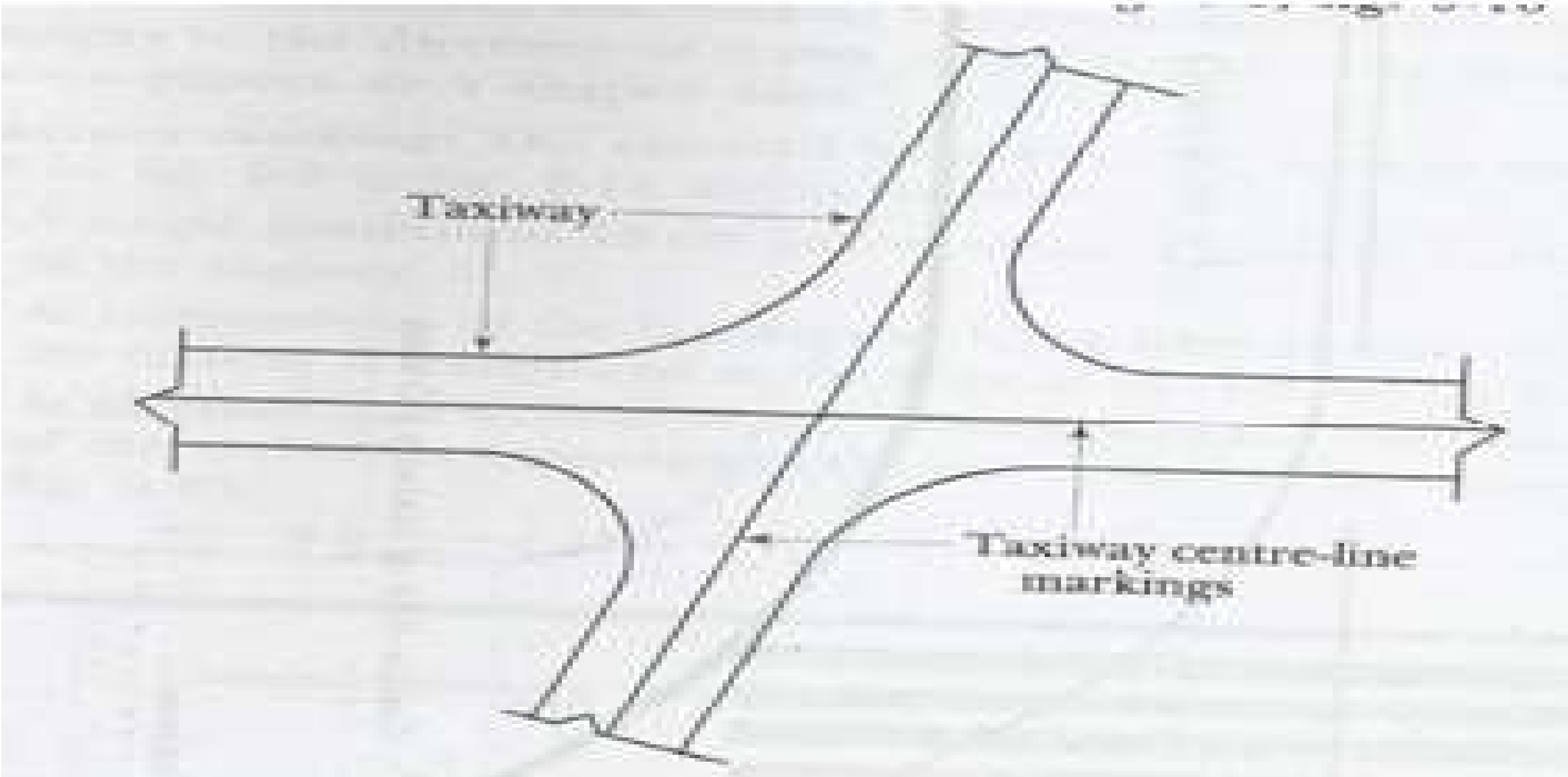


Taxiway marking

Taxiway Marking

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

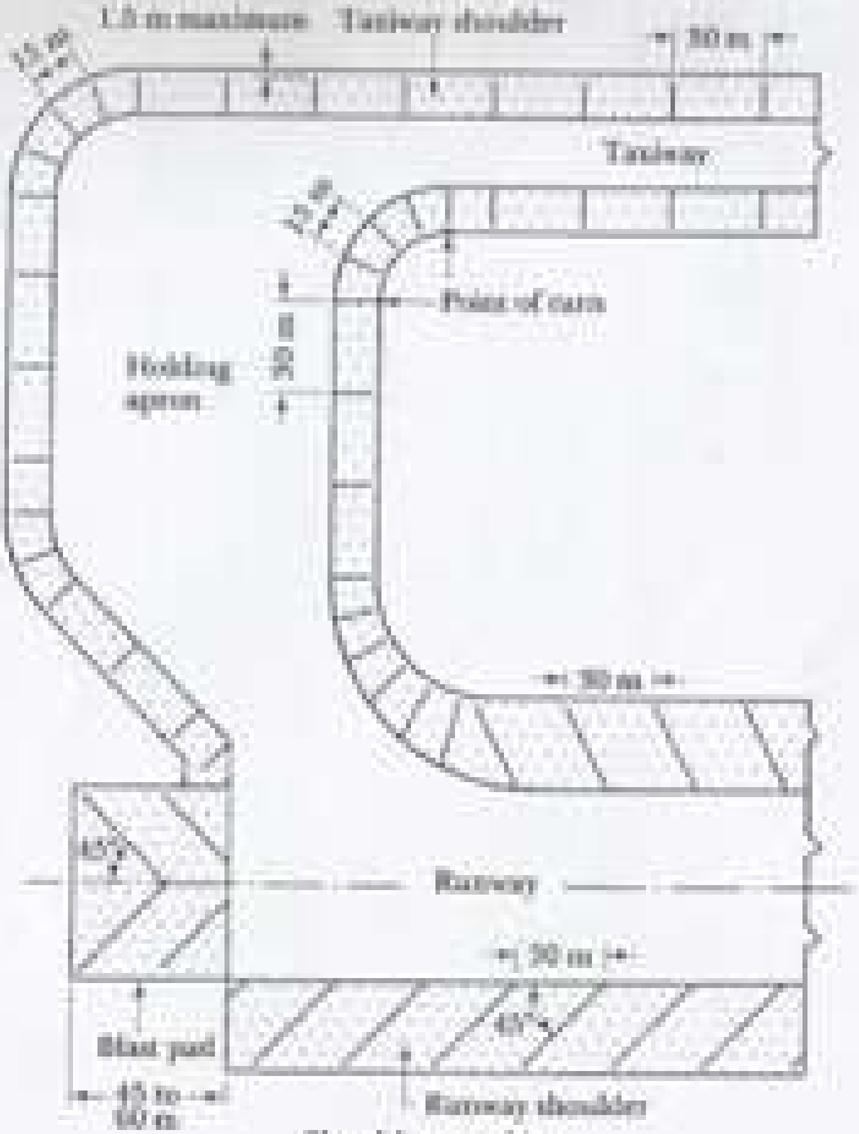


Taxiway marking

Shoulder Marking

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

Shoulder Marking

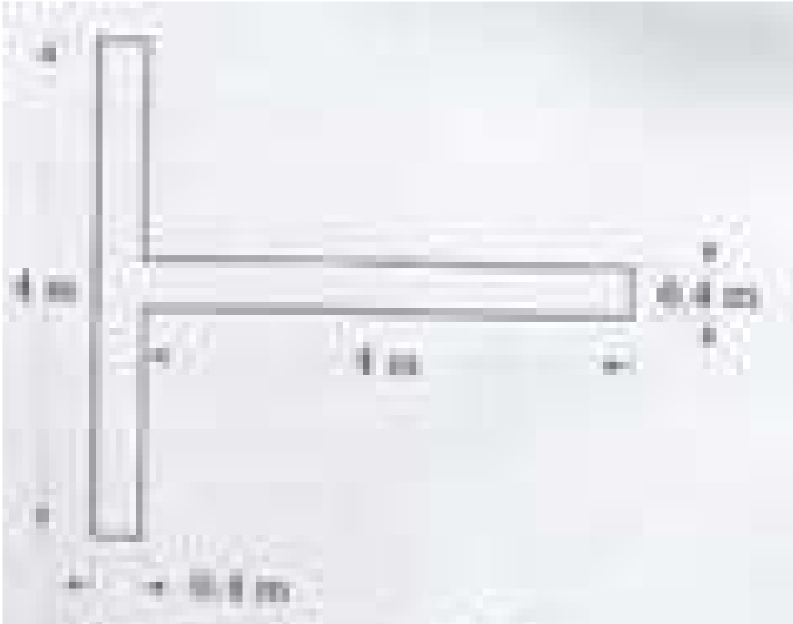


Shoulder marking

Landing Direction Indicator

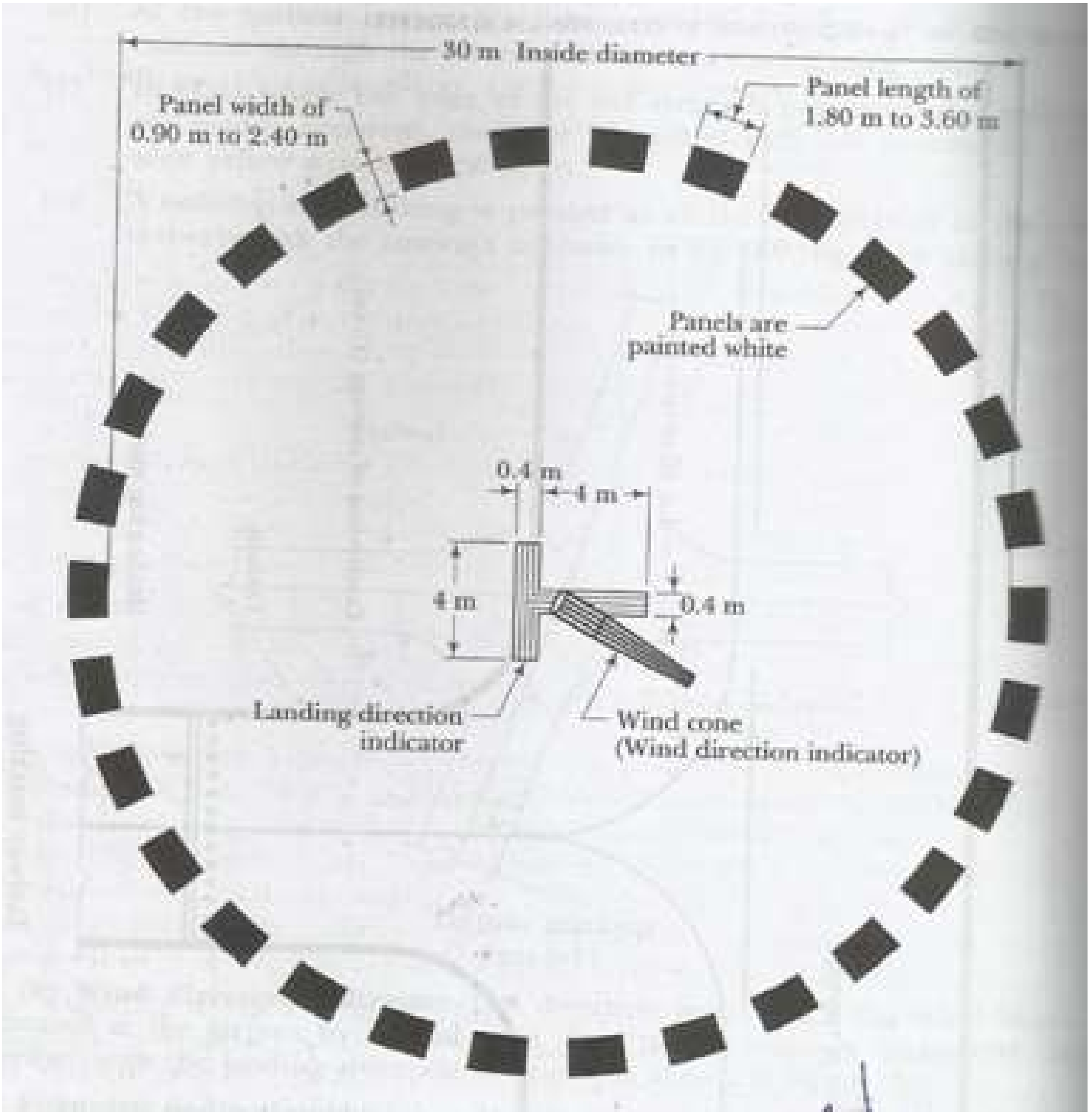
- To indicate the landing direction, an arrow or a tee is placed at the centre of a segmented circle.
- It indicates to the pilot the direction of the active runway of the airport.
- It is painted by orange or white color for being spotted with during day time and is lighted during night time.
- It is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

Landing Direction Indicator



Landing direction indicator

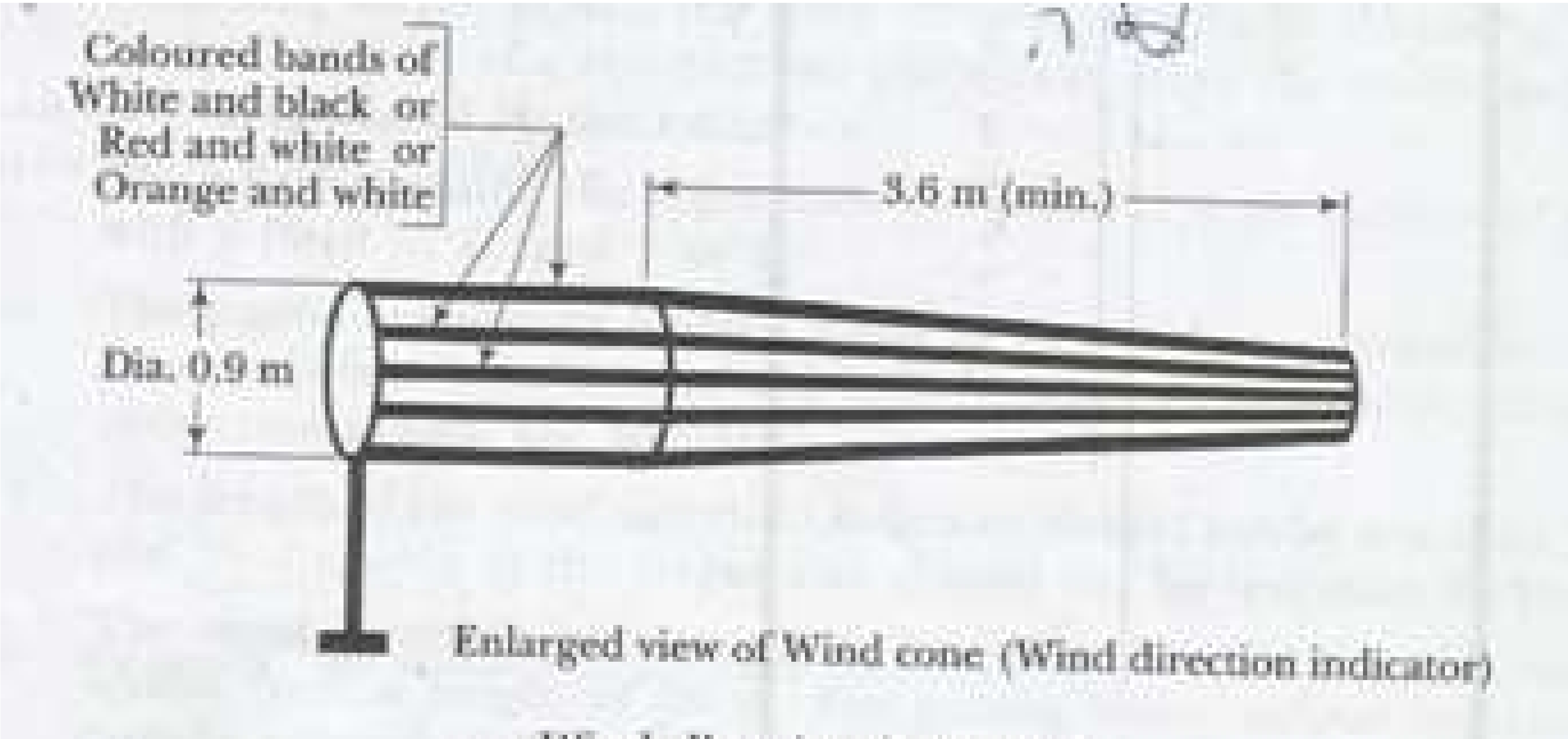
Landing Direction Indicator along with Wind Direction Indicator



Wind Direction Indicator

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

Wind Direction Indicator



Wind direction indicator

Thanks!

Week-(08)

MD Ehasan Kabir

Airport Lighting

- It is essential to provide adequate lighting in the airport during night for clear visibility of centre lines, edges and thresholds of runways, taxiways, aprons and hangars etc.
- In order to achieve uniformity and to guide the pilots for using the airport for which he may not be familiar, the colors and general arrangement of the airport lights for all civil airports have been standardized.
- Some of the major airports may contain nearly 30,000 lights.
- The bulbs should be checked regularly and the faulty bulbs are to be replaced immediately.

Factors Affecting Airport Lighting

The various factors affecting airport lighting are given below.

1. Airport Classification
2. Amount of Traffic
3. Availability of Power
4. Nature of aircraft using the airport
5. Type of Night Operations Planned
6. Type of Landing Surfaces Provided
7. Weather Conditions etc.

Airport Lighting

There are 9 elements of Airport Lighting.

1. Airport Beacon
2. Boundary Lighting
3. Approach Lighting
4. Threshold Lighting
5. Runway Lighting
6. Taxiway Lighting
7. Apron and Hangar Lighting
8. Lighting of Landing Direction Indicator
9. Lighting of Wind Direction Indicator

Airport Beacon

- A Beacon is a strong beam of light which is used to indicate any geographical location.
- The rotating airport beacon gives out white and green flashes in the horizontal direction 180^{o} apart.
- It rotates at 6 revolutions per minute and is usually mounted over the top of terminal building or hangar.

Airport Beacons

- White/Green – Civilian Airport
- White/Yellow – Seaport
- White/White/Green – Military
- White/Yellow/Green - Heliport

Boundary Lighting

- The entire boundary of the airfield is provided with lights at a centre to centre distance of about 90 m with a height of about 75 cm form the ground.

- When fence is provided, they can be placed at 3 m distance.

- To indicate hazardous approach, they are normally in red color.

Approach Lighting

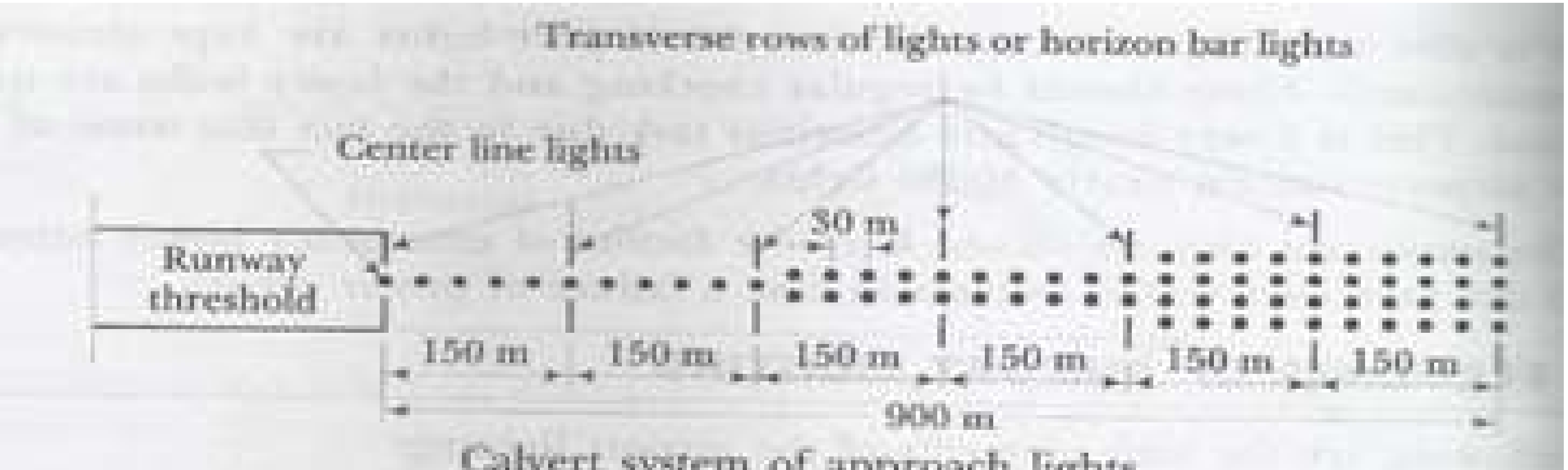
- Before the runway actually begins, there is a sequence of high-intensity lighting arrangement for a length of 900 m.
- These lights then give way to touch down zone lights from the threshold lighting.

- There are two types of arrangements for approach lighting

  1. Culvert system - widely used in Europe
  2. ICAO system - widely used in US

Culvert System of Runway Approach Lighting

- In culvert system, the approach lights are provided along the centre line for a length of 900 m from the threshold.
- The number of rows of lights will be decreasing in the direction of landing as shown in figure.
- **Number of transverse bars:** There are 6 transverse rows of lights of variable length placed at a centre to centre distance of 150 m.
- **Roll guidance:** The roll guidance is principally provided by the transverse rows of lights.



Calvert system of approach lights

ICAO System of Runway Approach Lighting

1. Number of transverse crossbars:

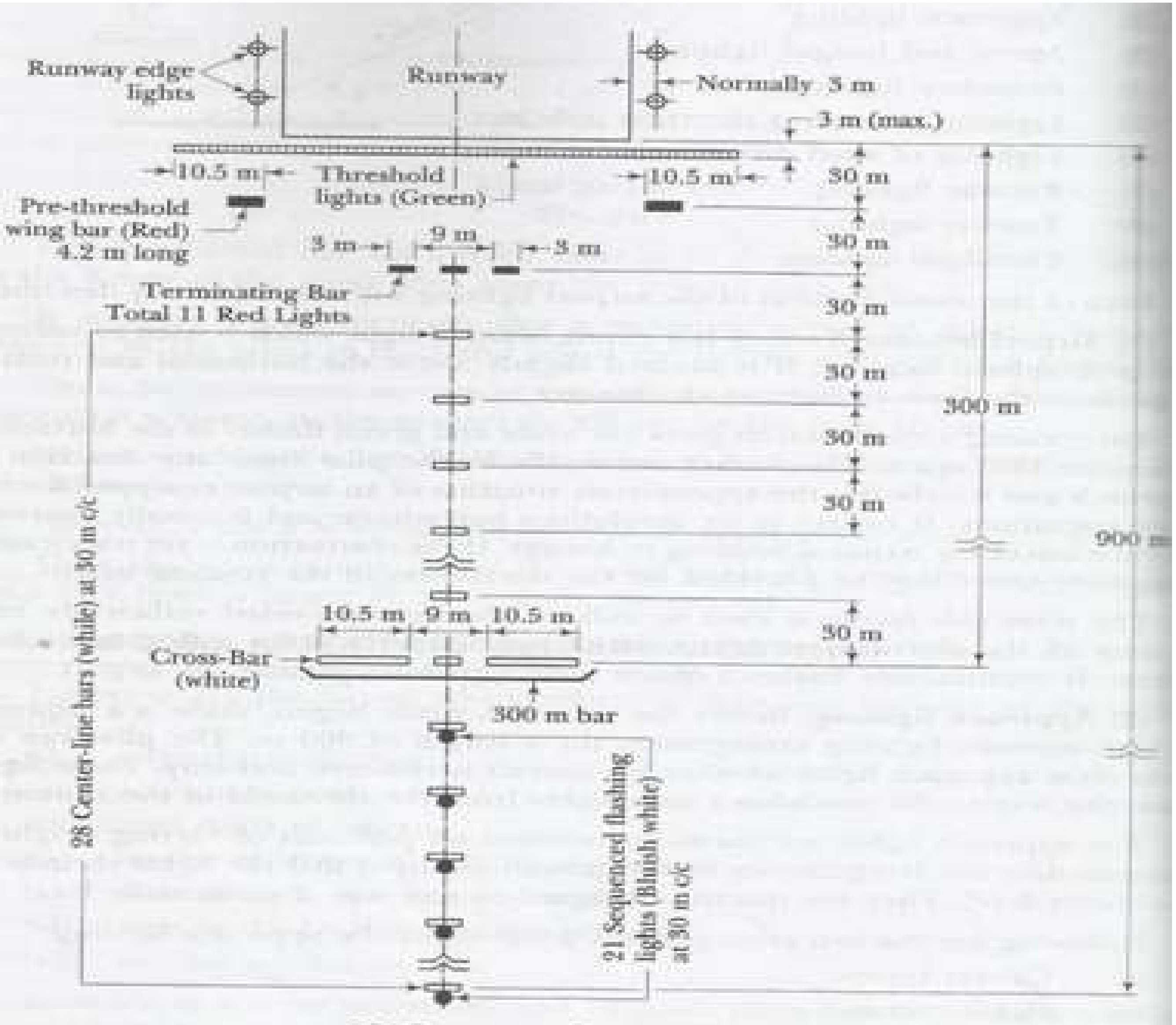
In ICAO system, there is only one crossbar 300 m from the threshold.

2. Roll Guidance:

In ICAO system, the roll guidance is provided by bars 4.2 m in length, placed at 30 m centre to centre on the extended centre-line of the runway and a single crossbar 300 m from the threshold.

The 4.2 m long bars consist of five closely spaced lights to give the effect of a continuous bar of light.

ICAO System of Runway Approach Lighting



ICAO system of approach lights

Threshold Lighting

- The identification of runway threshold is a major factor for the decision of the pilot to land or not to land.
- For this reason, the region near the threshold is given special lighting treatment.
- At large airports, the threshold is identified by a complete line of green lights extending across the entire width of the runway.
- The threshold lights in the direction of landing are green and in the opposite direction, they are red to indicate the end of runway.
- They must be of semi-flash type i.e. protruding not more than 12 cm above the surface.

Threshold lighting at Small Airports

- At small airports, the threshold is identified by 4 lights on each side of the threshold.

- They can be of elevated type i.e. protruding more than 12 cm above the surface

Runway Lighting

- After crossing the threshold, the pilot must complete a touch down and roll out on the runway.
- The planning of the runway lighting is carried out in such a way that the pilot gets enough information on alignment, lateral displacement, roll and distance.
- Earlier, night landings were made by flood-lighting the entire runway area.
- The more precise runway lighting arrangement which is now commonly used on all the major airports is known as the **narrow gauge pattern**.
- It makes use of the centre-line and touch down zone lights for operations in very poor visibility.

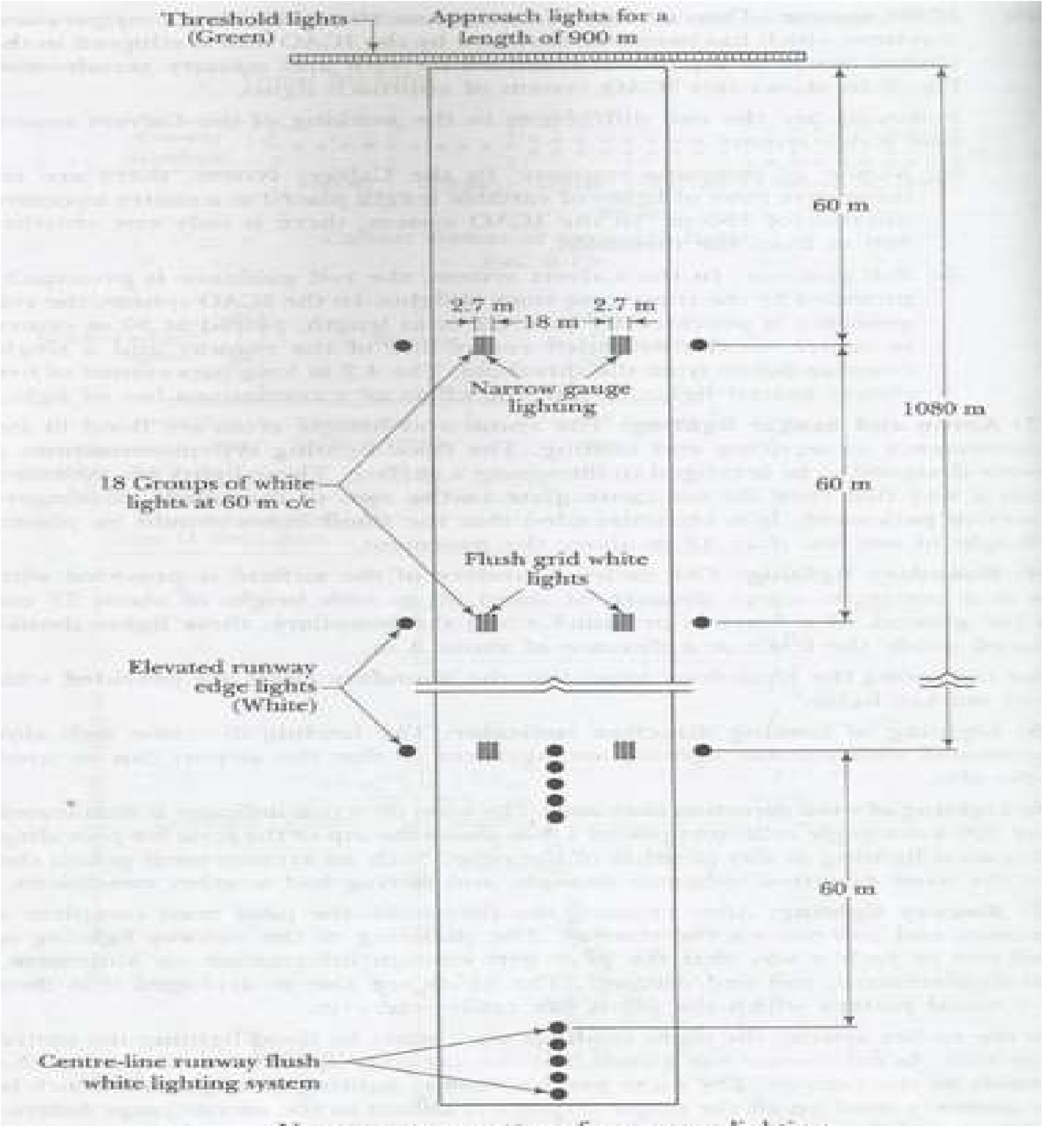
Black Hole Effect

- As the pilot crosses the threshold and continues to look along the centre-line, the principal source of guidance, namely, the edge lights have moved far to each side in their peripheral vision.
- As a result, the central area appears excessively black and the pilot is virtually flying blind except for the peripheral reference information.
- This is known as “black hole effect”.

Narrow gauge pattern for runway lighting

- To eliminate the black hole effect by increasing the intensity of edge lights was proved ineffective.
- Therefore, the narrow gauge pattern of runway lighting is introduced in which the central portion gets illuminated and the black hole effect is partly illuminated.
- The narrow gauge pattern forms a channel of light 18 m width up to 1140 m from the threshold and beyond this distance, the closely spaced lights are placed along the centre-line of the runway extending up to the other end of the runway.
- All the lights provided on the runway are white in color and of flush type. (i.e. they do not protrude more than 1 cm above the surface of the pavement)
- The runway edge lights are of elevated type and they are white in color except for the last 600 m of an instrument runway facing the pilot which are of yellow color to indicate a caution zone.

Narrow gauge pattern for Runway Lighting

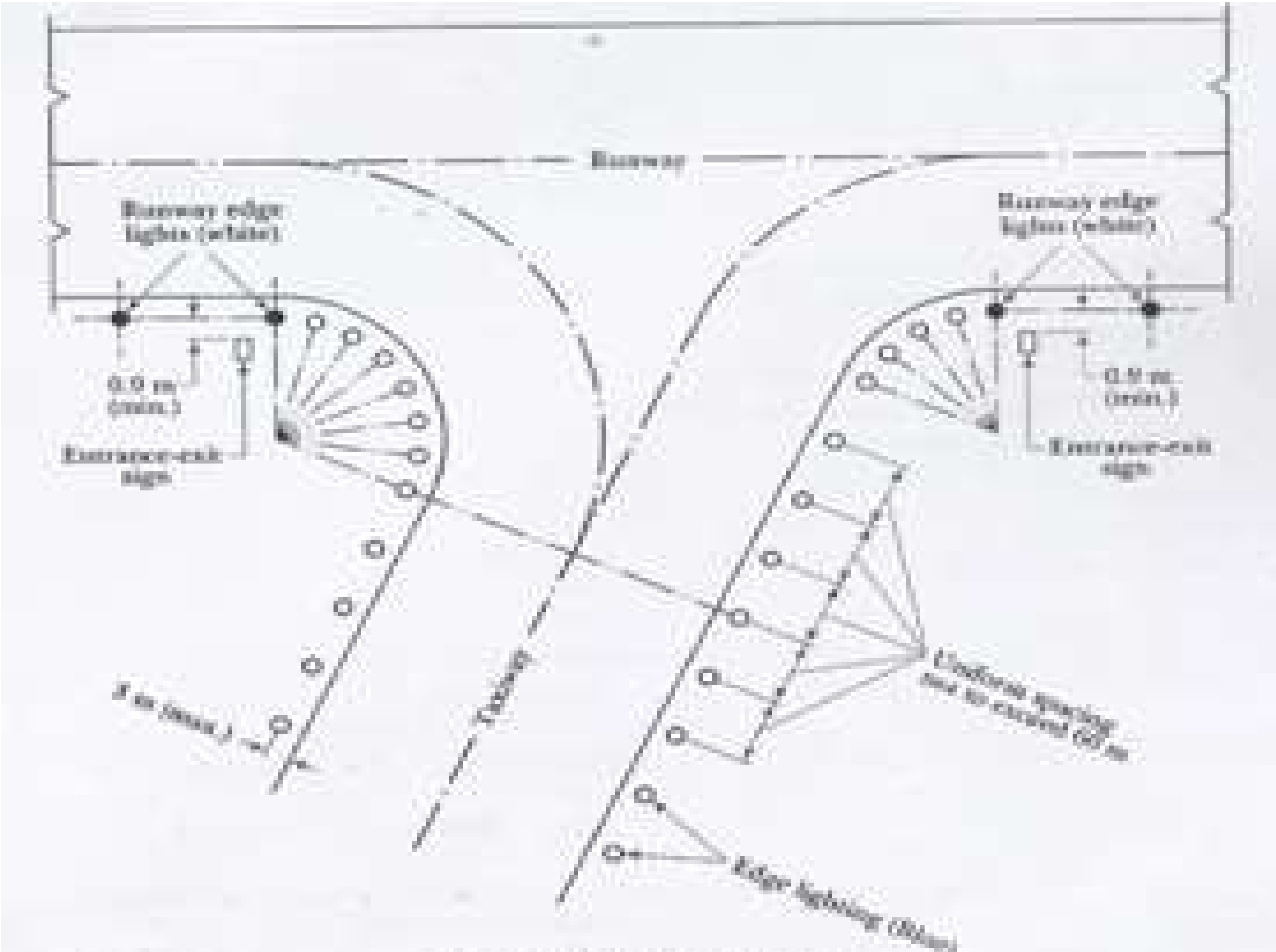


Narrow gauge pattern for runway lighting

Taxiway Lighting

1. For normal exits, the centre line lights are terminated at the edge of the runway.
2. At taxiway configurations, the lights continue across the intersections.
3. They are placed at a distance of 6 m to 7.5 m along the straight length and 3 m to 3.6 m along the curves.
4. The edge lights should not extend more than 75 cm above the pavement surface.
5. The exits from the runways should be so lighted that the pilots are able to locate the exits 360 m to 400 m ahead of the point of turn.
6. The taxiway edge lights are blue and the taxiway centre-line lights are green.

Taxiway Lighting



Typical taxiway lighting layout

Apron and Hangar Lighting

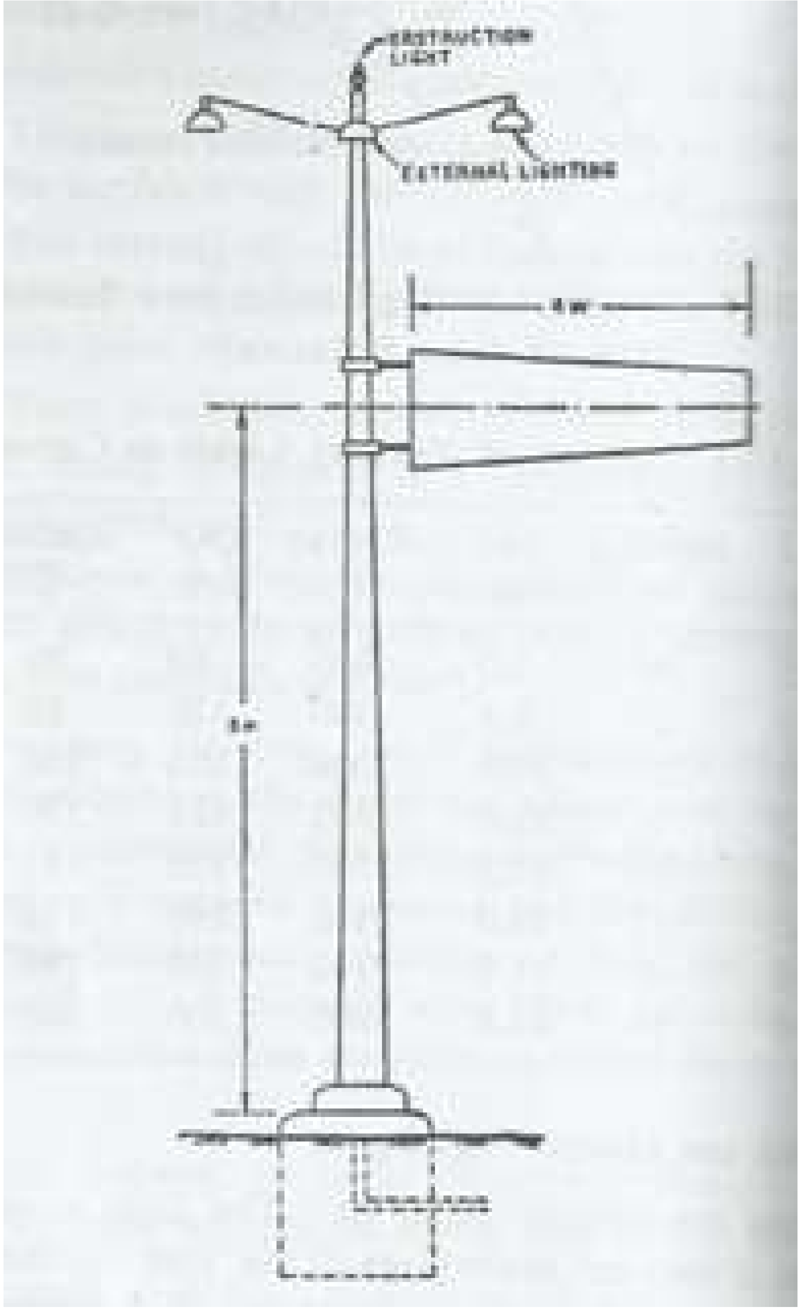
- Apron and Hangars are provided with flood lighting system in order to facilitate servicing loading and unloading.
- The light source is so mounted that it does not cause glare in the eyes of the pilots, the service personnel or the passengers.
- It is recommended that flood lights should be mounted at least 12 m (40 ft) above the pavement.

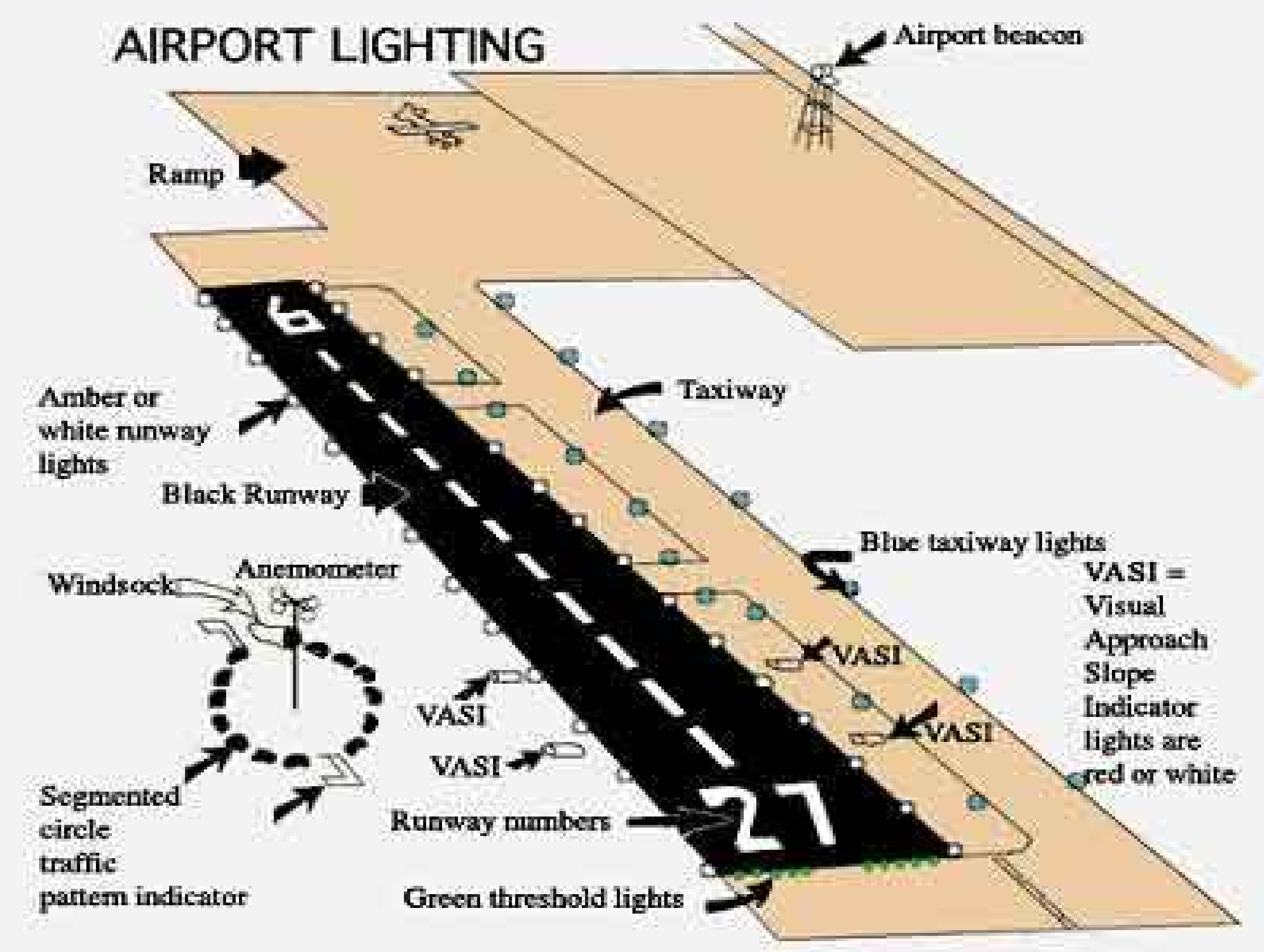
Lighting of Landing Direction Indicator

- The landing direction indicator usually a tee or arrow is illuminated with suitable lighting arrangement so that it is visible to the pilot during night also.

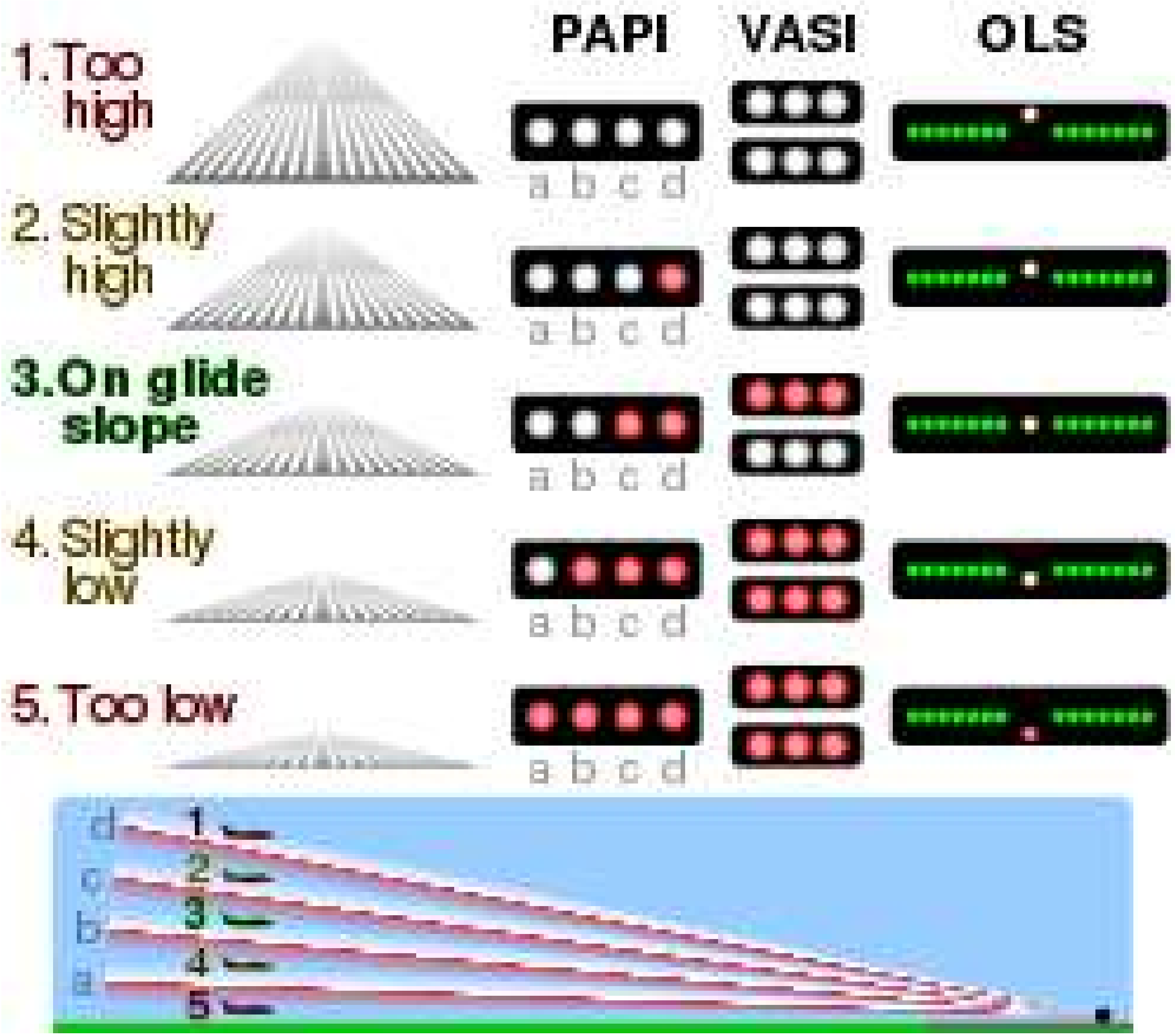
Lighting of Wind Direction Indicator

- The wind direction indicator is illuminated by 4 x 200 watts angle reflectors placed 1.8 m above the top of the cone for providing a continuous lighting at any position of the cone, so that it can be used during night or bad weather condition.





AIRPORT LIGHTING
Airport beacon
Ramp
Taxiway
Amber or white runway lights
Black Runway
Blue taxiway lights
VASI = Visual Approach Slope Indicator lights are red or white
Windsock
Anemometer
VASI
VASI
VASI
VASI
Segmented circle traffic pattern indicator
Runway numbers
Green threshold lights
6
27



PAPI
VASI
OLS
1. Too high
2. Slightly high
3. On glide slope
4. Slightly low
5. Too low
a b c d
a b c d
a b c d
a b c d
a b c d
d
c
b
a
1
2
3
4
5

Thanks!

Week-(09)

MD Ehasan Kabir

Air Safety

- Every day, morethan1000 flights take to the sky and land without incident.
- But some times accidents may also occur as was happened in the case of previous years.
- International Air Transport Association has established a safety group (SG) and Operations Committee (OPC) in close cooperation with the member airlines and Strategic Partners in 2013.
- This group has formulated a Six Point Safety Strategy as a comprehensive approach to identify organizational, operational and emerging safety issues.
- The Strategy focuses in six key areas.

Air Safety & Regulation issues

The IATA Safety group 6 point safety strategy includes:

1. Reduce Operational Risk

The area of reducing operational risks comprises safety issues related to:

1. Runway Safety (Debris on runway eg. Hail or dust)
2. Misleading information (misinformed printed doc)
3. Faulty instrument
4. Ice & Snow
5. Engine failure
6. Structural failure due to metal fatigue
7. Bird Strike
8. Volcanic ash
9. Pilot error
10. Resource Mismanagement

Air Safety

11. Improper communication
12. Electromagnetic Influence
13. Loss of Control In-flight
14. Controlled Flight Into Terrain
15. Collisions
16. Software programming problem
17. Virus Problem

Safety and Regulation Issues

2. Enhance Quality and Compliance

3. Advocate for Improved Aviation Infrastructure

- Phasing out NDB/VOR approaches and accelerating the implementation of **approaches with vertical guidance** (APV)
- Airport (runway & ramp infrastructure)
- Air Navigation harmonization and standardization

4. Support Consistent Implementation of Safety Management System

- implementing the Safety Management System (SMS)
- Safety performance monitoring
- Analysis and dissemination of information
- Safety promotion and facilitation

Safety and Regulation Issues

5. Support Effective Recruitment and Training

- Air Traffic Control (ATC)
- Next Generation of Aviation Professionals (N G A P)
- Ground Handling Agents (GHA)
- The IATA Training and Qualification Initiative (ITQI) should modernize and harmonize the training of existing and future generations of pilots and maintenance technicians.

Air Safety & Regulation Issues

6. Identify and Address Emerging Safety Issues

- Identifying and addressing safety issues related to:
- Restrictions on transportation of Lithium Batteries
- Safe Integration of Remotely Piloted Aircraft Systems (RPAS)
- GNSS signal interference – GNSS jamming and Space weather – Global Navigation Satellite System is particularly prone to unintended and malicious Radio Frequency Interference (RFI) due to the extremely low power level of the signal
- Laser attacks - Pointing a laser at an aircraft can be hazardous to pilots and has resulted in arrests.

Other Regulation Issues

1. Lease procedures of airports
2. Restriction on ownership and control of airport infrastructures
3. Building control
4. Environmental Management Regulations
5. Economic Regulations

Legislation

1. Airports Act - 1996
2. Airports Regulations – 1997
3. Building controls Regulations – 1997
4. Environmental Protection Act – 1997
5. Protection of airspace - 1997
6. Sydney airport demand management act – 1997
7. Sydney airport demand management Regulations – 1997
8. Environment Protection & Biodiversity Conservation Act - 1999

Thanks!

Week-(10)

MD Ehasan Kabir

Curvature of Track

Definition

- A railway track on a straight is an ideal condition.
- However, this ideal condition may not be continued in a track.
- Therefore, curvatures are provided inevitably on a railway track
  - to bypass obstacles,
  - to provide longer and easily traversed gradients, and
  - to pass a railway line through obligatory or desirable locations.

DEFINITION

- Horizontal curves are provided when a change in the direction of the track is required and
- Vertical curves are provided at points where two gradients meet or where a gradient meets level ground.

Disadvantages of providing curvature

- Restriction in speed, limiting the length of trains and prevent the use of heavy type of locomotives.
- Maintenance cost of track increases due to increase in the wear and tear of parts of tracks.
- Danger of collision, derailment or other form of accident is increased.
- Running of train is not smooth.

Restriction of providing curvature

- Bridge and tunnels
- Approaches to bridges
- Steep gradients
- Stations and yards
- Level crossing

Degree / Radius of curvature

- A simple curve is designated either by its degree or by its radius.
- The degree of a curve (ϴ) is the angle subtended at its centre by a chord of 30 m length.

Degree of curvature

- If AB = 30 m and $\angle AOB = 1°$ the degree of curvature of this curve is 1 degree.
- The greater the degree of curvature, the curve will be sharper and consequently, the smaller will be its radius.

Relationship between radius and Degree of curvature

- 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 m chord

$$D = \frac{360}{2\pi R} \times 30$$

$$D \approx \frac{1719}{R} \; (R \; in \; meter)$$

Superelevation or Cant

- When a train is moving on a curved path, it has a constant radial acceleration which produces centrifugal force.
- In order to counteract this force, the outer rail of the track is raised slightly higher than the inner rail. This is known as the *Super-elevation or Cant*.

Purposes of providing Super-elevation

- To ensure safe and smooth movements of passengers and goods on the track.
- It counteract the effect of the centrifugal force by producing centripetal force on the train.
- It prevents derailment and reduces the creep and as well as side wear of rails.
- It provides equal distribution of wheel loads on two rails.
- It results in the decrease of maintenance cost of the track.

Equilibrium Superelevation

v = velocity in m/s

W = weight of the moving train

F = centrifugal force acting on the vehicle

g = acceleration due to gravity in m/s

R = radius of curvature in m

G = gauge of track

e = super-elevation in m

α = angle of inclination

S = length of inclined surface

Equilibrium Superelevation

$$\tan\theta = \frac{\text{superelevation}}{\text{gauge}} = \frac{e}{G}$$

Also,

$$\tan\theta = \frac{\text{centrifugal force}}{\text{weight}} = \frac{F}{W}$$

Equilibrium Superelevation

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

From these equations

$$\frac{e}{G} = \frac{F}{W}$$

or

$$e = F \times \frac{G}{W}$$

$$e = \frac{W}{g} \times \frac{V^2}{R} \times \frac{G}{W} = \frac{GV^2}{gR}$$

Equilibrium Superelevation

If V = velocity in km/hr, then ***e*** would be

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

$$e = \frac{V^2\,G}{1.27\ \mathrm{R}}$$

Calculation of Super-Elevation

- Calculate the superelevation for a 2° BG transitioned curve on a high-speed route. The speed for calculating the equilibrium superelevation as decided by the chief engineer is 80 km/h.

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

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

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

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

Cant deficiency

- Under a certain conditions, it is not possible to provide the equilibrium cant.
- In figure ??, a branch line diverges from a main line. AP and BQ are the inner and outer rails respectively of main line.
- BD and AC are the inner and outer rails respectively of the branch line.
- Let S1 and S2 be the amounts of the super-elevation required form main and branch lines respectively.

Cant deficiency

- Therefore, following condition should be satisfied:
  - Considering main line, the point B should be higher than point A by amount S1.
  - Considering branch line, the point A should be higher than point B by amount S2.

Cant Excess

- ???

Cant deficiency / Cant Excess

- It is obvious that it is impossible to comply with both the conditions simultaneously.
- Therefore, under such condition a small amount of deficiency in super-elevation is permitted without reducing speed.
- This is known as *"cant deficiency"* or *"deficiency in super-elevation"*.

Procedures of providing super-elevation

- The equilibrium cant on branch line is calculated by usual formula by assuming suitable speed on branch line.
- The permissible cant deficiency is deducted from the equilibrium cant.
- The result thus obtained will represent the negative super-elevation to be given on the branch line.
- Evidently, the negative cant on branch line will be equal to the maximum cant permitted on the main line.
- The permissible cant deficiency is added to the maximum cant permitted on the main line and correspondingly, the restricted speed on the main line is worked out.

Permissible Cant deficiency

Gauge	*Group*	*Normal cant deficiency (mm)*	*Remarks*
BG	A and B	75	For BG group
BG	C, D, and E	75	A and B routes; 100 mm cant deficiency permitted only for nominated stock and routes with the approval of the CE
MG	–	50	
NG	–	40	

Workout problem

- A 6 degrees curve branches off from a 3 degrees main curve in an opposite direction in a layout of a BG line. If the speed on the branch line is restricted to 35 kmph, determine the speed restriction on the main line. Permissible cant deficiency is 75mm.

Workout problem

- SE for branch line, $e = \frac{V^2 G}{1.27 \text{ R}}$

$$e = \frac{35^2 \times 1.676}{1.27 \times \frac{1719}{6}}$$

$$e = 5.622\ cm$$

Negative super-elevation = (5.622 – 7.5) = - 1.878 cm

Maximum super-elevation can be provided on the main line =

= 1.878+7.5 = 9.378 cm

Therefore, speed for main line, $e = \frac{V^2 G}{1.27 \text{ R}}$

$$9.378 = \frac{V^2\, 1.676}{1.27 \times \frac{1719}{3}}$$

V = 63.93 kmph

Workout problem

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V = 63.93 kmph

FACTORS AFFECTING SUPER-ELEVATION

- Frictional resistance
- Coning of wheel
- Weight of the vehicle
- Speed of the train

Bending of rails on curve

- If the curvature is less than 3° then the curve is considered as the flat curve.
- In that case, the rails are placed in the curved position by sleepers
- If the curvature is greater 3° then the rails are bend.

VERSINE OF A CURVE

- The versine of a curve is the perpendicular distance of the midpoint of a chord from the arc of a circle.

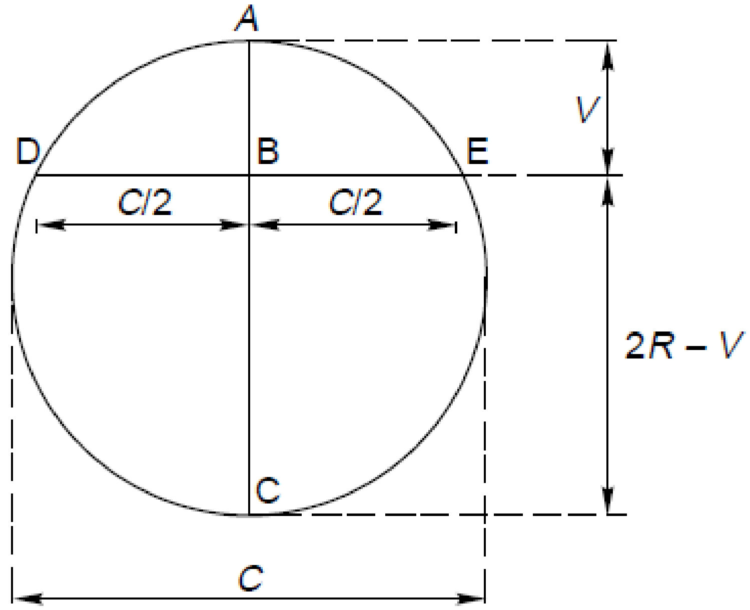
Relationship between radius and versine of a curve

- The relationship between the radius and versine of a curve can be established from this figure.
- Let R be the radius of the curve, C be the length of the chord, and
- V be the versine of a chord of length C.

Relationship between radius and versine of a curve

- AC and DE being two chords meeting perpendicularly at a common point B, simple geometry can prove that –

$$AB \times BC = DB \times BE$$



Relationship between radius and versine of a curve

Or, $V(2R - V) = (C/2) \times (C/2)$

Or, $2RV - V^2 = C^2/4$

V being very small, V^2 can be neglected. Therefore,

$$2RV = \frac{C^2}{4}$$

$$V = \frac{C^2}{8R}$$

Relationship between radius and versine of a curve

In this Eq. V, C, and R are in the same unit, say, metres or centimetres.

This general equation can be used to determined versines if the chord and the radius of a curve are known.

Case I: Values in metric units

The versine formula can also be written as-

$$\frac{V}{100} = \frac{C^2}{8R}$$

where R is the radius of the curve, C is the chord length in metres, and V is the versine in centimetres, or

$$V = \frac{C^2 \times 100}{8R} \qquad \frac{12.5C^2}{R} \text{cm or } \frac{125C^2}{R} \text{mm}$$

Case II: Values in FPS units

When R_1 is the radius in feet, C_1 is the chord length in feet, and V_1 is the versine in inches, the above formula can be written as

$$\frac{V_1}{12} = \frac{C_1^2}{8R_1}$$

or

$$V_1 = \frac{1.5C_1^2}{R_1}$$

Safe Speed on Curves

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

Safe Speed on Curves

- For BG and MG

  Transitioned curves – $V = 4.4\sqrt{R - 70}$

where V is the speed in km/h and R is the radius in metres.

- For NG

  Transitioned curves – $V = 3.65\sqrt{R - 6}$

Transition Curve

- Definition
- Requirements
- Formula

Week-(11)

MD Ehasan Kabir

Maintenance

Necessity of Track Maintenance

The railway track should be maintained properly in order to

- enable trains to run safely at the highest permissible speeds and
- provide passengers a reasonable level of comfort during the ride.

Necessity of Track Maintenance

Track maintenance becomes a necessity due to following reasons:

- Due to the constant movement of heavy and high-speed trains-
  - the packing under the sleepers becomes loose and track geometry gets disturbed.
  - The gauge, alignment, and longitudinal as well as cross levels of the track thus get affected adversely and the safety of the track is jeopardized.

Necessity of Track Maintenance

- Due to the vibrations and impact of high-speed trains,
  - the fittings of the track come undone and
  - there is heavy wear and tear of the track and its components.
- The track and its components get worn out as a result of the weathering effect of rain, sun, and sand.

Advantages of Track Maintenance

- A well-maintained track offers a safe and comfortable journey to passengers.
- If the track is not maintained properly, it will cause discomfort to the passengers and
- in extreme cases may even give rise to hazardous conditions that can lead to derailments and a consequential loss of life and property.
- Track maintenance ensures that such situations do not arise.

Advantages of Track Maintenance

- The chances of derailment and accident are considerably reduced.
- The delicate goods can be conveniently and safely carried in the trains.
- The high speeds of the trains can be maintained.
- The life of rolling stock and track is increased.
- There is reduction in the operational cost of the trains.
- The train journeys become easy, smooth and comfortable.

Advantages of Track Maintenance

- Small maintenance jobs done at the appropriate time such as tightening a bolt or key, hammering the dog spike, etc., helps in avoiding loss of the concerned fitting and thus saving on the associated expenditure.
- When track maintenance is neglected for a long time, it may render the track beyond repair, calling for heavy track renewals that entail huge expenses.

Essentials of Track Maintenance

For a track to serve its purpose well, the following characteristics are required of it.

- The gauge should be correct or within the specified limits.
- There should be no difference in cross levels except on curves, where cross levels vary in order to provide superelevation
- Longitudinal levels should be uniform

Essentials of Track Maintenance

- The alignment should be straight and kink-free
- The ballast should be adequate and the sleepers should be well packed.
- There should be no excessive wear and tear of the track and all its components and fittings should be complete.
- Track drainage should be good and the formation should be well maintained.

Operation of Maintenance

The maintenance of railway track consists of the following operations:

- Through packing
- Systematic overhauling
- Picking up slacks

- Examination of rails, sleepers, and fastenings
- Squaring of sleepers
- Aligning the track
- Gauging
- Lubrication of rail joints

END

Week-(12)

MD Ehasan Kabir

Points and Crossing

DEFINITION

- Point and Crossings are peculiar arrangement used in permanent way (railway track) to guide the vehicle for directional change.
- It is an arrangement which diverts the train from one track to another, either parallel to or diverging from the first track.

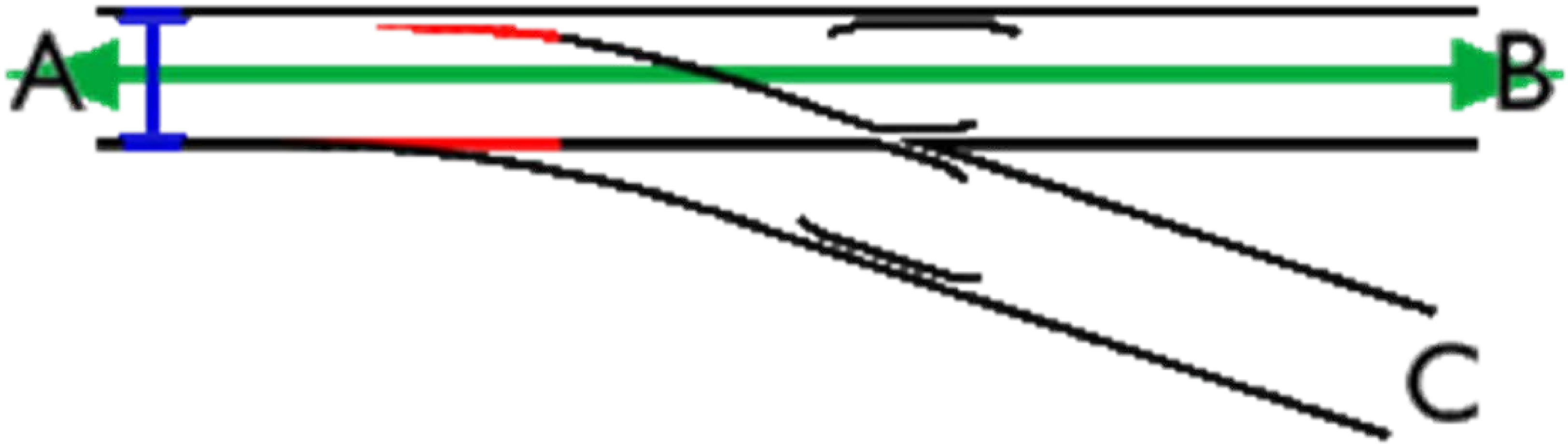
Points and corssing

- Point (Switch): the device that is use to divert the wheels
- Crossing: gaps in the rail that enables the actual diversion
- Turnout: Complete set of points and crossing including the main (lead) rail

  - Left hand turnout

  - Right hand turnout

Right Hand Turn out



Components of a turnout

i) Turnout- The term denotes points and crossing with the lead rails.

ii) Tongue rail - It is tapered moveable rail, connected at its thickest end to running rail.

iii) Stock rail – It is the running rail, against which a tongue rail functions.

iv) Switch – A pair of tongue with stock rail with necessary connections and fittings.

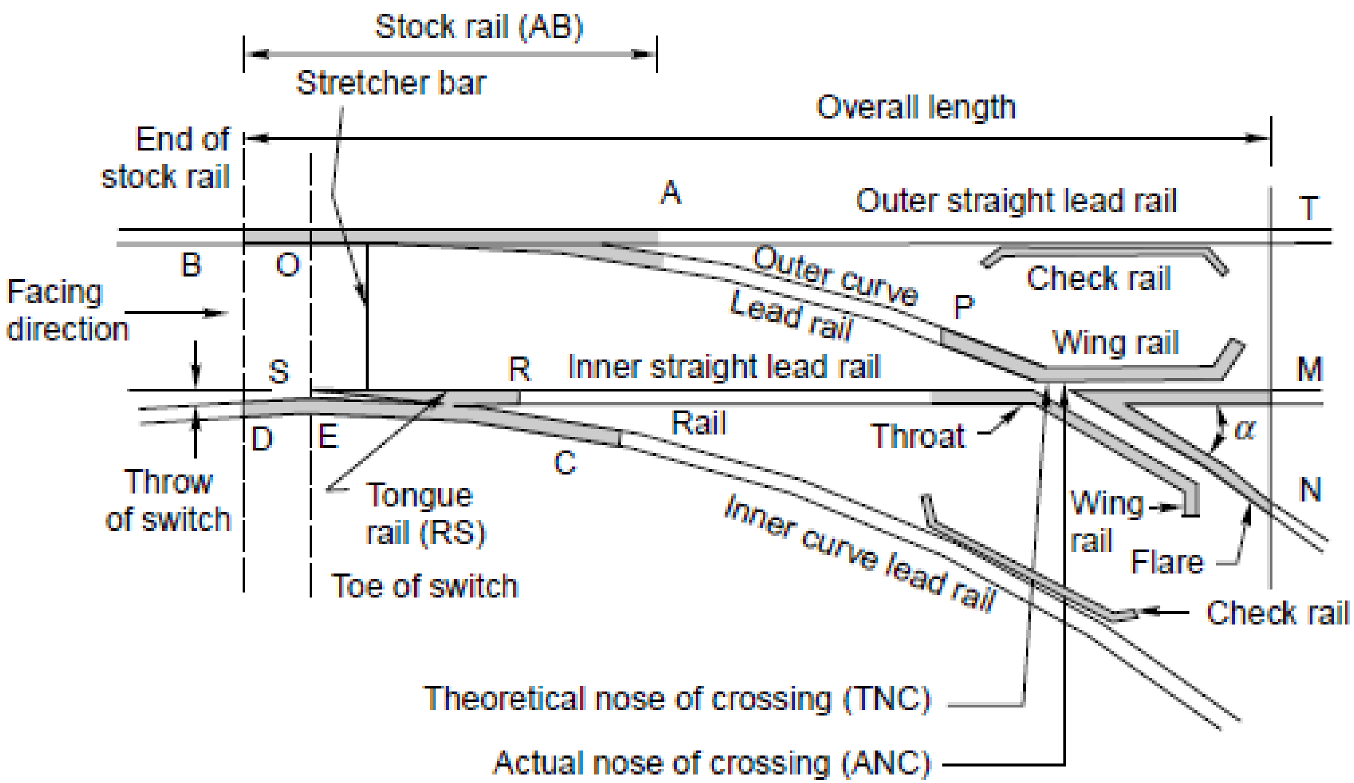
v) Points – A pair of tongue rail with their stock rails are termed as points.

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

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

viii) Lead – The track portion between heels of switch to the beginning of crossing assembly is called lead.

COMPONENTS OF A TURNOUT



i) Turnout

ii) Tongue rail

iii) Stock rail

iv) Switch

v) Points

vi) Crossing

vii) Heel of switch

viii) Lead

Video

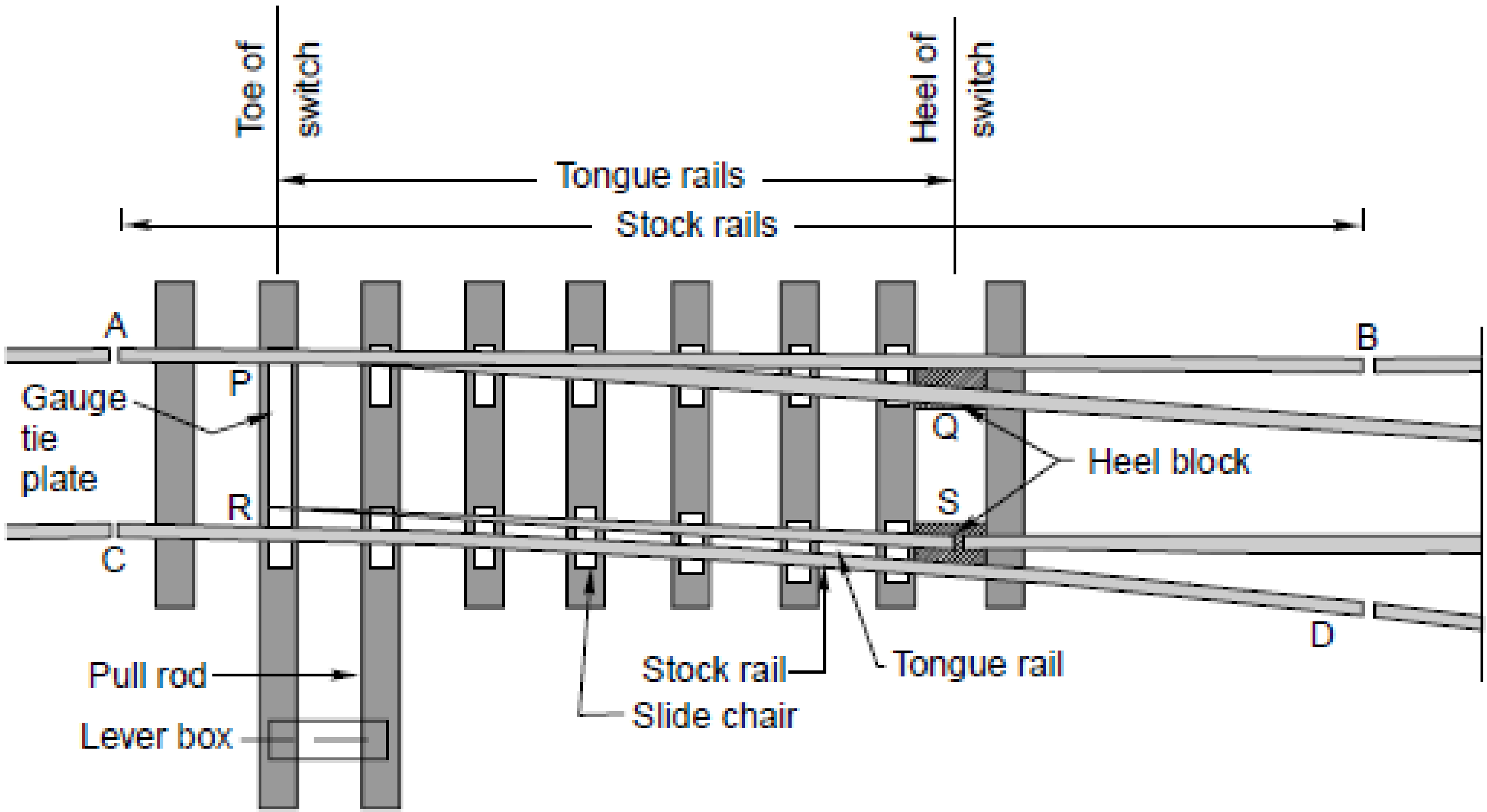
Switch (A pair of Points/tongue rails)

- A switch, is a set of points, in which a mechanical installation enabling railway trains to be guided from one track to another.
- Rails which lie between the 2 stock rails
- End portion of the tongue rail is called toe and is connected by stretcher bar .
- It is the moving part of the switch which diverts the train from one track to the other.

Details of a switch

- A pair of stock rails, AB and CD.
- A pair of tongue rails, PQ and RS, also known as switch rails. The tapered end of the tongue rail is called the toe and the thicker end is called the heel.
- A pair of heel blocks which hold the heel of the tongue rails is held at the standard clearance or distance from the stock rails.
- A number of slide chairs to support the tongue rail and enable its movement towards or away from the stock rail.
- Two or more stretcher bars connecting both the tongue rails close to the toe, for the purpose of holding them at a fixed distance from each other.
- A gauge tie plate to fix gauges and ensure correct gauge at the points.

DETAILS OF A SWITCH



Requirements of a switch

- Requirements of tongue rails
- Top and side of the tongue rail is tapered in such a way that they do not bear any load
- Tongue rail is higher than stock rail by 6mm
- Half thickness of the tongue rail at the toe should be closely fitted within the stock rail

Stretcher bar

- Used to connect the toe of the tongue rails so that both of the tongues moves through the same distance
- Generally 2 or 3 bars are used near and behind the toe

CHECK RAILS

- They are the rails which are used guide the outer wheel flange of the train.
- To ensure that the train does not derail.

Wing rail

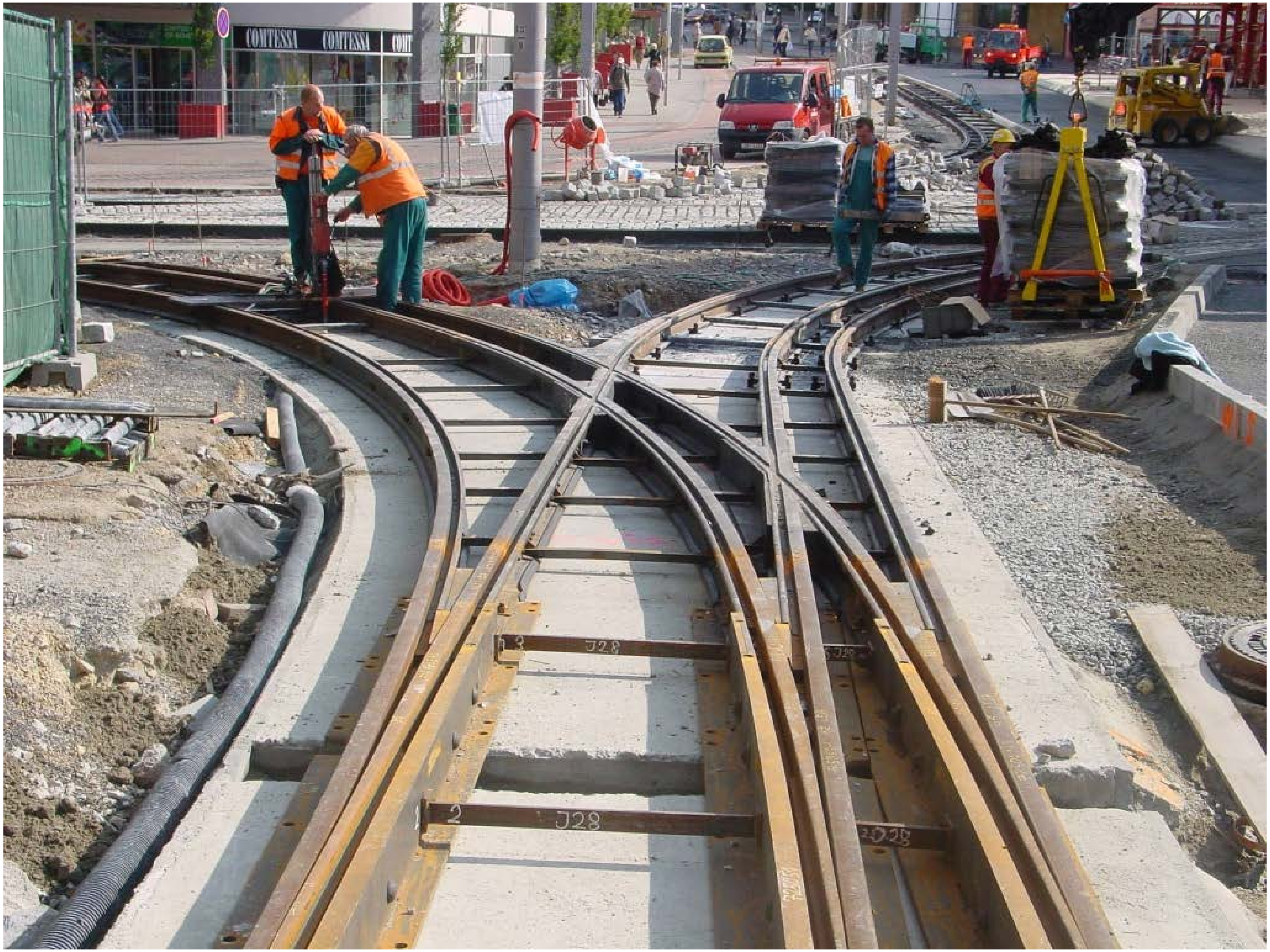
- Rails which are used to guide the inner wheel flange of the train.

Crossing

- It is a arrangement of rails introduced at the junction where two rails cross to permit the wheel flange of a railway vehicle to pass from one track to another track.

How many Crossing ???

How many Crossing ???



Types of Switches

- Stub switch
- Split switch

Stub switch

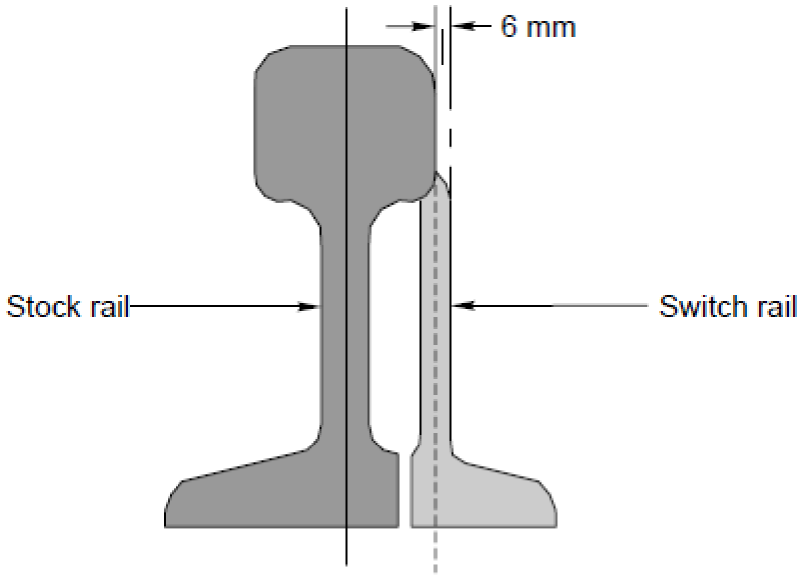
- First developed for steam railways, was one in which the straight and diverging tracks were completely separate and side by side.
- The throw of the switch was about 5 inches.
- No separate tongue rail was provided.
- This type is no more in use and has been replaced by Split Switch.

Shapes of switches

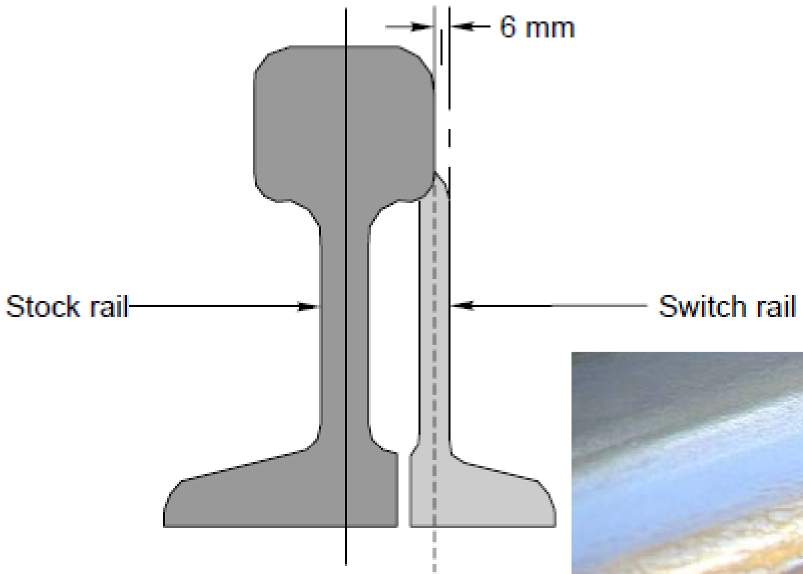
- Undercut switches
- Straight cut switches
- Over-riding / composite switches

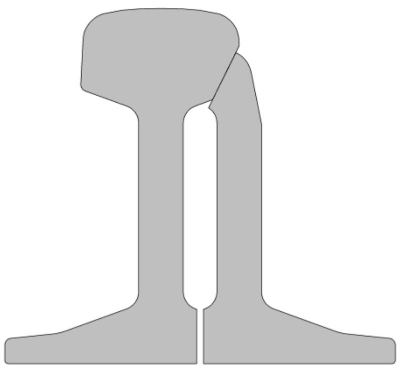
Undercut switches

- cut out a portion of flange at the foot of the stock rail so that toe of tongue rail is accommodated under head of the stock rail.
- The disadvantage of this type of switch is that it becomes weak because flange portion is cut out.
- These switch are generally used in narrow gauge lines.

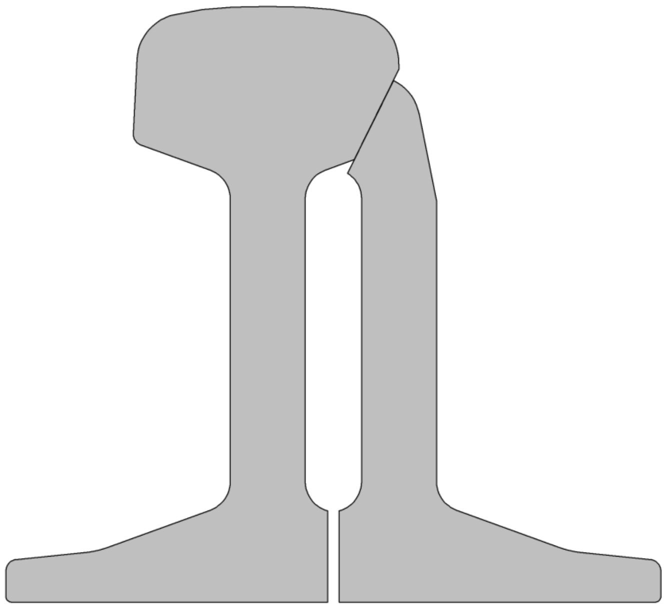


Undercut switches





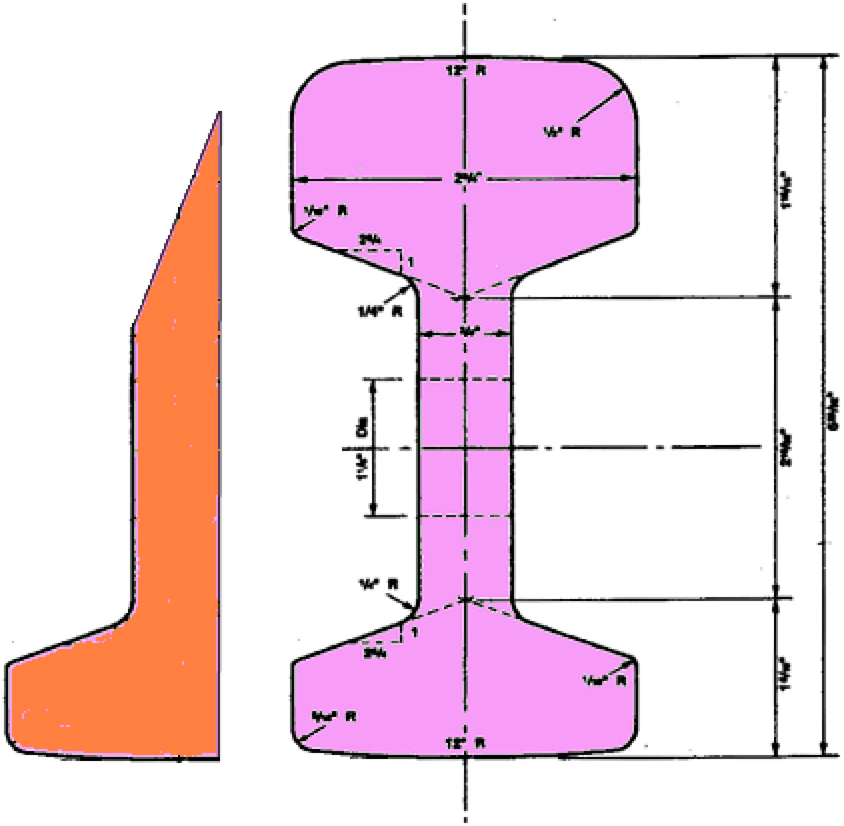
Undercut switches



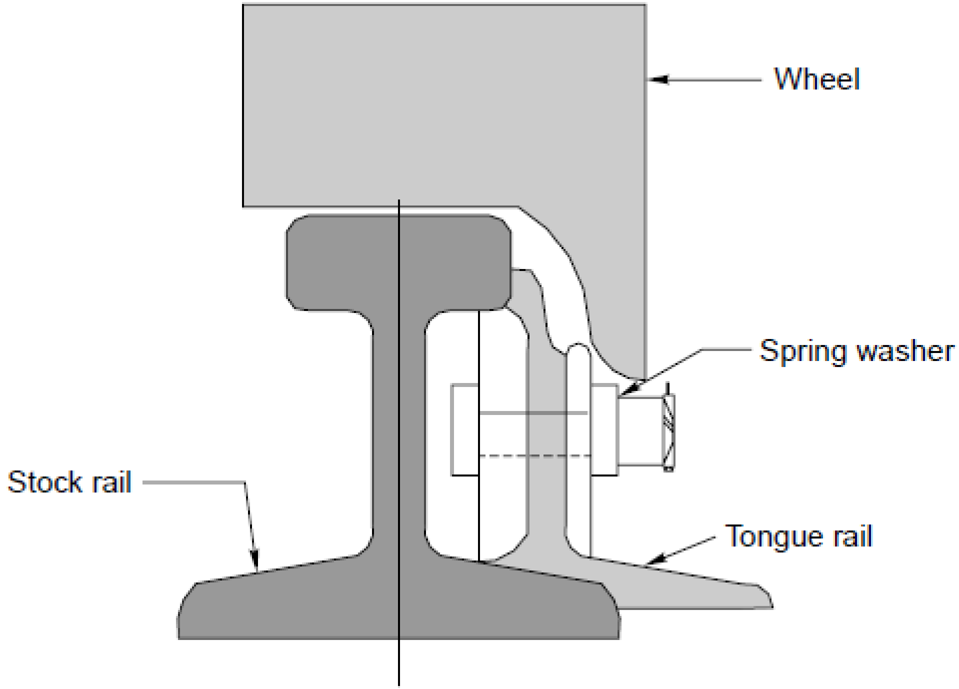
Straight cut switches

- In this type the tongue rail is cut straight in the line with the stock rail.
- This is done to increase the thickness of toe of the tongue rail, which increases its strength
- This type of switch is suitable for Bull Headed rails.

STRAIGHT CUT SWITCHES



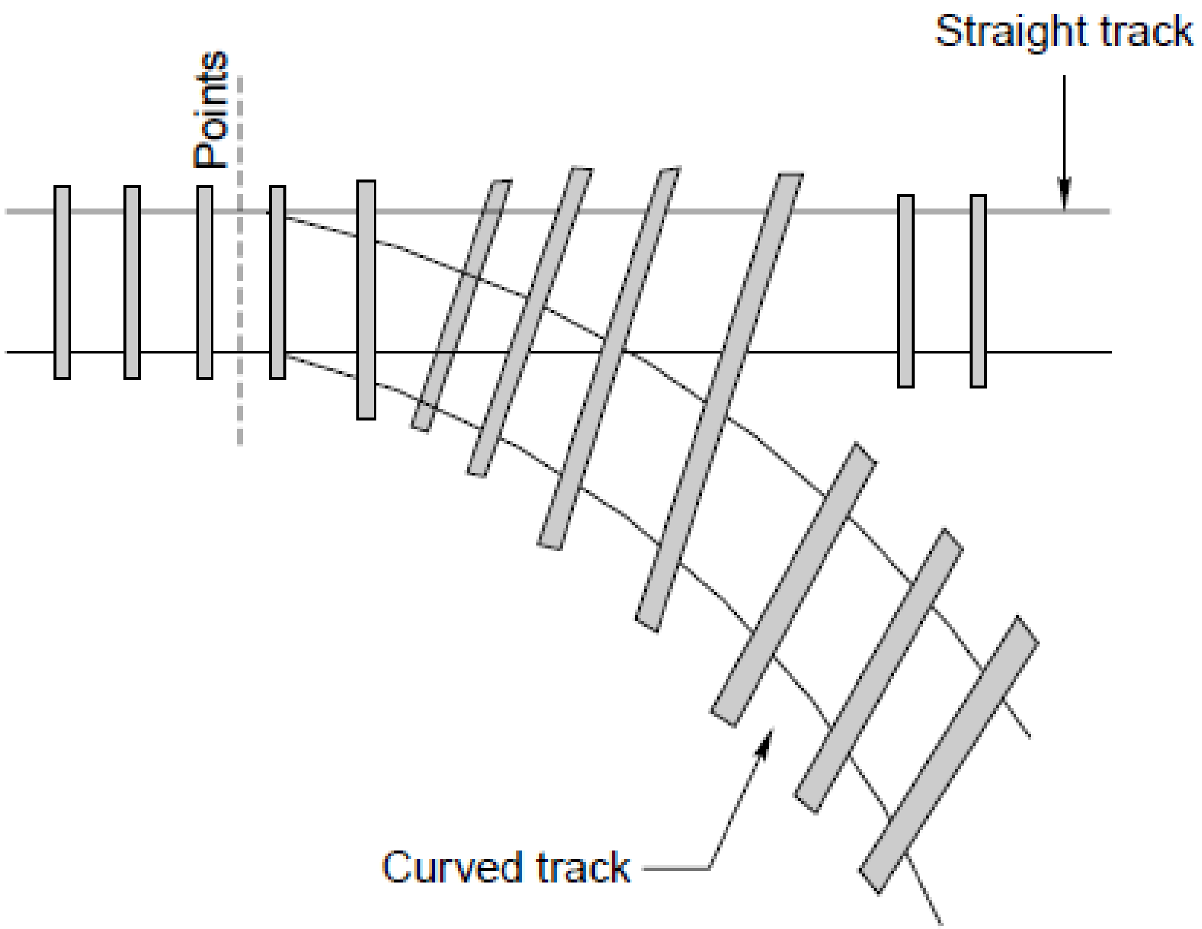
Over-riding switches



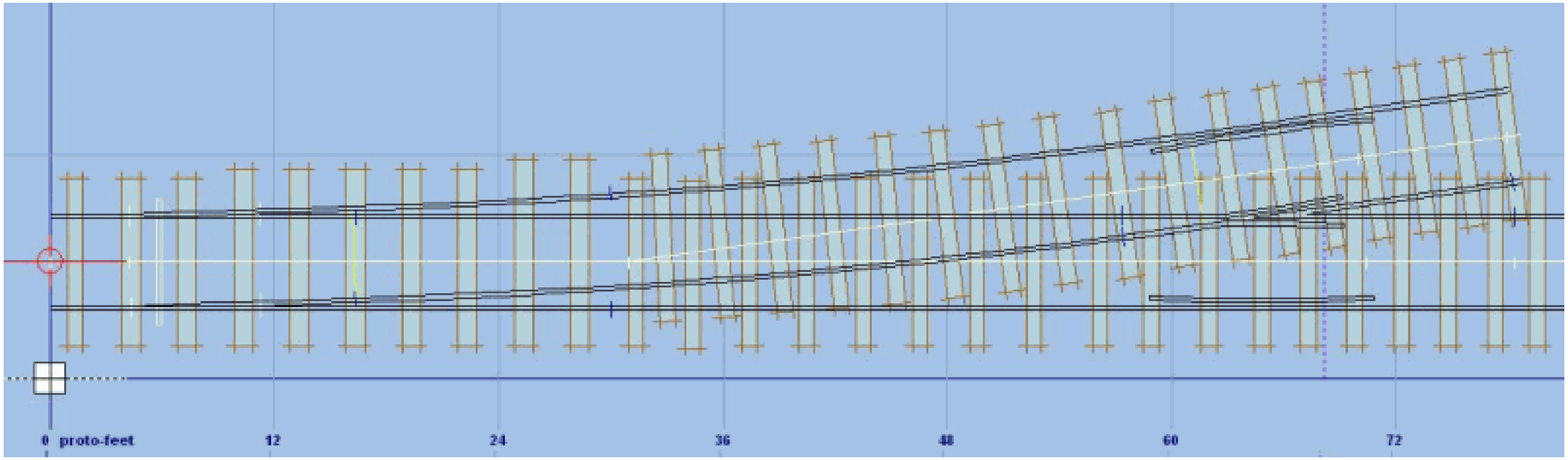
Sleeper laid for points and crossing

- Through sleepers
- Interlaced sleepers

THROUGH SLEEPERS



Interlaced sleepers

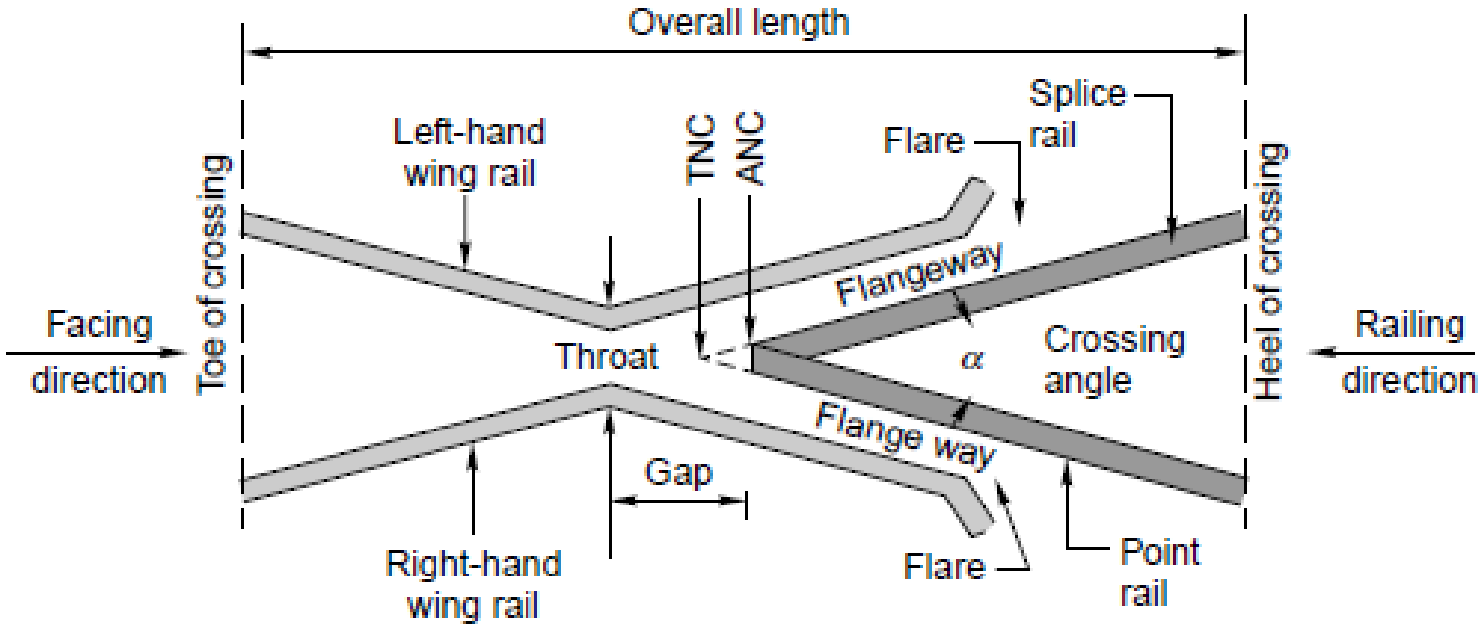


INTERLACED SLEEPERS

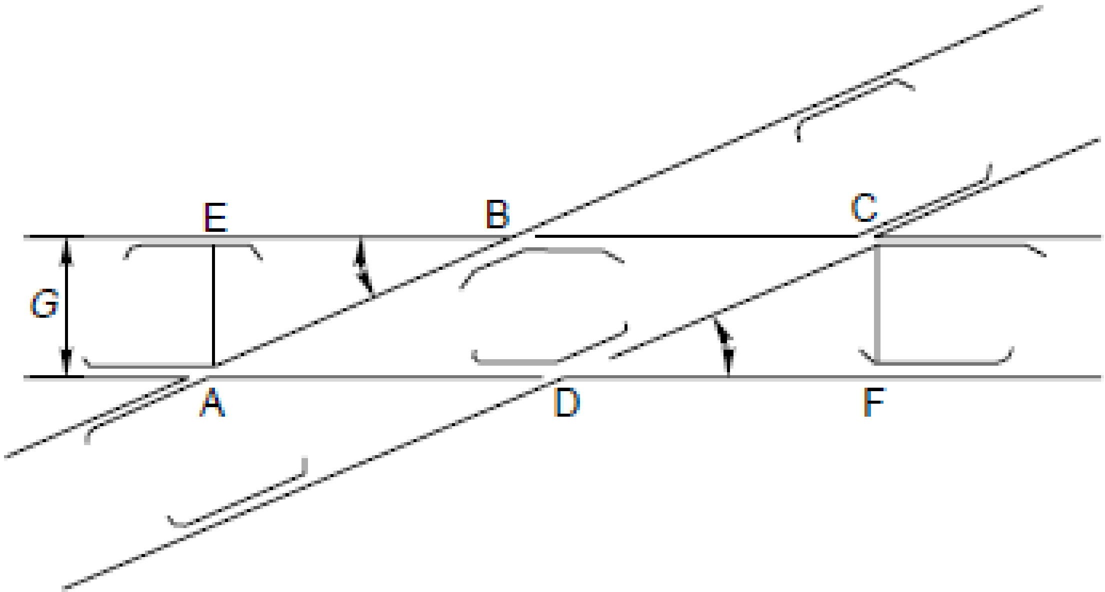
Types of crossing

- Ordinary or acute crossing or V crossing
- Double or obtuse crossing or diamond crossing
- Square crossing

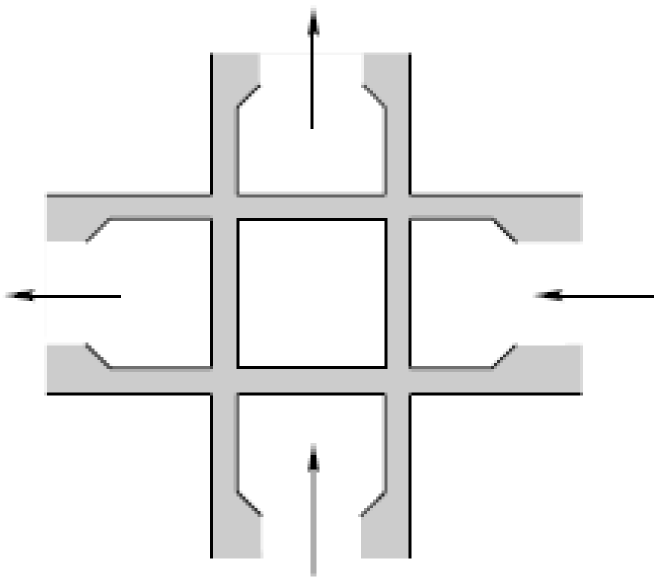
DETAILS OF A V CROSSING



Diamond crossing



Square crossing



Laying of points and crossing

- Self study

Week-(13)

MD Ehasan Kabir

CHAPTER
25

Train Resistance and Tractive Power

Introduction

Various forces offer resistance to the movement of a train on the track. These resistances may be a result of the movement of the various parts of the locomotives as well as the friction between them, the irregularities in the track profile, or the atmospheric resistance to a train moving at great speed. The tractive power of a locomotive should be adequate enough to overcome these resistances and haul the train at a specified speed.

25.1 Resistance Due to Friction

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

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

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

Rolling resistance This occurs due to rail-wheel interaction on account of the movement of steel wheels on a steel rail. The total frictional resistance is given by the empirical formula

$$R_1 = 0.0016W \qquad (25.1)$$

where R_1 is the frictional resistance independent of speed and W is the weight of the train in tonnes.

25.2 Resistance Due to Wave Action

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

$$R_2 = 0.00008WV \tag{25.2}$$

where R_2 is the resistance due to wave action and track irregularities on account of the speed of the train, W is the weight of the train in tonnes, and V is the speed of the train in km/h.

25.3 Resistance Due to Wind

When a vehicle moves with speed, a certain resistance develops, as the vehicle has to move forward against the wind. Wind resistance consists of side resistance, head resistance, and tail resistance, but its exact magnitude depends upon the size and shape of the vehicle, its speed, and wind direction as well as velocity. Wind resistance depends upon the exposed area of the vehicle and the velocity and direction of the wind. In Fig. 25.1, V is the velocity of wind at an angle θ. The horizontal component of wind, $V\cos\theta$, opposes the movement of the train. Wind normally exerts maximum pressure when it acts at an angle of 60° to the direction of the movement of the train.

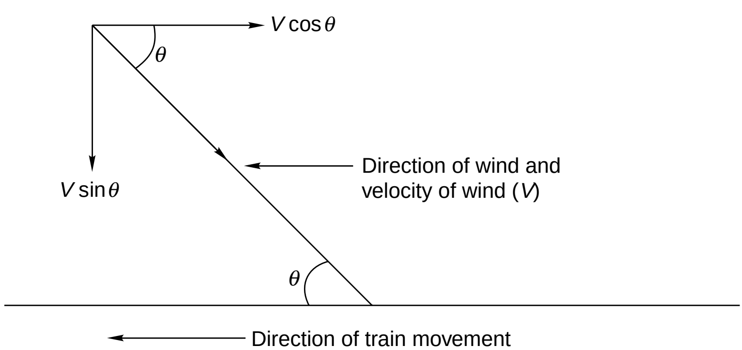


Fig. 25.1 Resistance due to wind

Wind resistance can be obtained by the following formula:

$$R_3 = 0.000017AV^2 \tag{25.3}$$

where A is the exposed area of vehicle (m^2) and V is the velocity of wind (km/h).

Studies also support the fact that the important factors that affect wind resistance are the exposed area of the vehicle and the relative velocity of the wind vis-à-vis that of the vehicle. In fact, wind resistance depends upon the square root of the velocity of the wind. The following formula has been empirically established on the basis of studies.

$$R_3 = 0.0000006WV^2 \tag{25.4}$$

where R_3 is the wind resistance in tonnes, V is the velocity of the train in km/h, and W is the weight of the train in tonnes.

25.4 Resistance Due to Gradient

When a train moves on a rising gradient, it requires extra effort in order to move against gravity as shown in Fig. 25.2.

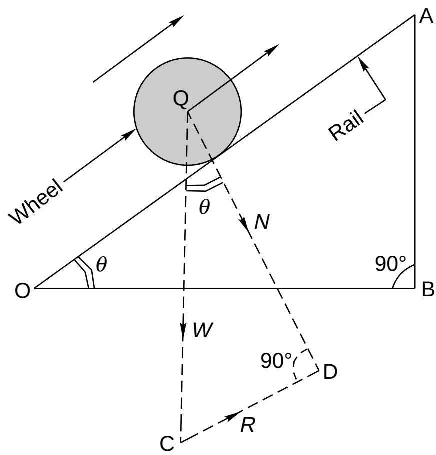


Fig. 25.2 Resistance due to gradient

Assuming that a wheel of weight W is moving on a rising gradient OA, the following forces act on the wheel.

(a) Weight of the wheel (W), which acts downward
(b) Normal pressure N on the rail, which acts perpendicular to OA
(c) Resistance due to rising gradient (R_4), which acts parallel to OA

These three forces meet at a common point Q and the triangle QCD can be taken as a triangle of forces. It can also be geometrically proved that the two triangles QCD and AOB are similar. From ΔQCD,

$$R = W \sin\theta$$

From ΔOAB,

$$R = W \times \frac{\text{AB}}{\text{OA}}$$

In actual practice, the gradients are very small and, therefore, OA is approximately equal to OB. Therefore,

$$R = W = \frac{\text{AB}}{\text{OB}} = \frac{W \times \%\ \text{slope}}{100}$$

$$R_4 = \frac{W \times \%\ \text{slope}}{100} \tag{25.5}$$

This means that if the weight of the train is 50 t and the slope is 1 in 50 (2%), the resistance due to gradient is

$$R_4 = \frac{W \times \%\ \text{slope}}{100} = \frac{50 \times 2}{100} = 1\text{t}$$

It may be noted here that when a train ascends a slope, extra effort is required to overcome the resistance offered by the gradient. The position is, however, reversed when the train descends a slope and the resistance offered by the gradient helps in the movement of the train.

25.5 Resistance Due to Curvature

When a train negotiates a horizontal curve, extra effort is required to overcome the resistance offered by the curvature of the track. Curve resistance is caused basically because of the following reasons (Fig. 25.3).

(a) The vehicle cannot adapt itself to a curved track because of its rigid wheel base. This is why the frame takes up a tangential position as vehicle tries to move in a longitudinal direction along the curve as shown in Fig. 25.3. On account of this, the flange of the outer wheel of the leading axle rubs against the inner face of the outer rail, giving rise to resistance to the movement of the train.

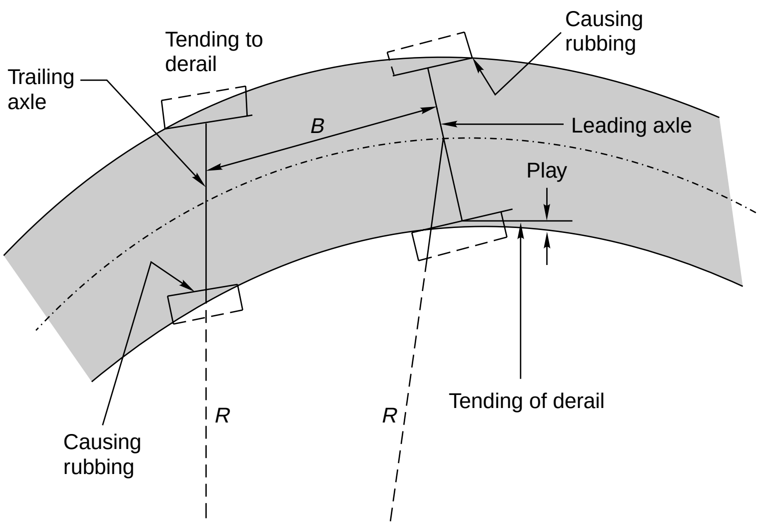


Fig. 25.3 Resistance due to curvature

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

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

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

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

The value of curve resistance can be determined by the following equation:

$$\text{Curve resistance} = C\frac{FG}{R} \tag{25.6}$$

where F is the force of sliding friction, G is the gauge of the track, R is the mean radius of the curve, and C is the constant, which is dependent on various factors. This equation indicates that

(a) curve resistance increases with increase in gauge width and
(b) resistance is inversely proportional to the radius, i.e., it increases with an increase in the degree of the curve.

Empirical formulae have been worked out for curve resistance, which are as follows:

$$\text{Curve resistance for BG } (R_5) = 0.0004WD \tag{25.7}$$
$$\text{Curve resistance for MG } (R_5) = 0.0003WD \tag{25.8}$$
$$\text{Curve resistance for NG } (R_5) = 0.0002WD \tag{25.9}$$

where W is the weight of the train in tonnes and D is the degree of the curve. It means that for a 4° curve on a BG line, the curve resistance for a train weighing 250 t would be 0.0004 × 250 × 4 = 0.4 t.

Compensated gradient for curvature

Curve resistance is quite often compensated or offset by a reduction in the gradient. In this way, the effect of curve resistance is translated in terms of resistance due to gradient. The compensation is 0.04% on BG, 0.03% on MG, and 0.02% on NG lines for every 1° of the curve. This will be clear through the solved example given below.

Example 25.1 Calculate the compensated gradient on a BG track with a 4° curvature on a ruling gradient of 1 in 200.

Solution

Ruling gradient = 1 in 200 = 0.5%
Compensation for curvature = 0.04 × 4 = 0.16%
Compensated gradient = 0.05 – 0.16 = 0.34% = 1 in 294

Special characteristics of curve resistance

Certain characteristics of curve resistance have been observed over the years. These are enumerated here.

(a) Curve resistance increases with the speed of the train.
(b) Curve resistance depends upon the central angle of the curve. For example, if there are two curves of different radii, but with the same central angle, the total curve resistance would be the same.
(c) Though curve resistance depends on the weight of the train, the length of the train has no appreciable effect on it.
(d) Curve resistance is less with new rails compared to that with old rails.
(e) Depending upon various factors, curve resistance can be as low as 0.20 kg per tonne per degree curve when the track is in good condition and may go as high as 1.0 kg per tonne per degree curve for worn out rails, rough tracks, and other unfavourable conditions of the track.

25.6 Resistance Due to Starting and Accelerating

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

Resistance on starting, $R_6 = 0.15W_1 + 0.005W_2$ (25.10)

Resistance due to acceleration, $R_7 = 0.028aW$ (25.11)

where W_1 is the weight of the locomotive in tonnes, W_2 is the weight of the vehicles in tonnes, W is the total weight of the locomotive and vehicle in tonnes, i.e. $W_1 + W_2$, and a is the acceleration, which can be calculated by finding the increase in velocity per unit time, i.e. $a = (V_2 - V_1)/t$, where V_2 is the final velocity, V_1 is the initial velocity, and t is the time taken.

Table 25.1 summarizes the various resistances faced by a train.

Table 25.1 Details of various resistances

Nature of resistance	*Value of resistance*	*Remarks*
Resistance due to friction (R_1)	$0.0016W$	Resistance independent of speed
Resistance due to wave action, track irregularities, and speed (R_2)	$0.00008WV$	Resistance dependent on speed
Resistance due to wind, or atmospheric resistance (R_3)	$0.0000006WV^2$	Resistance dependent on square root of speed
Resistance due to gradient (R_4)	$\frac{W \times \% \text{ of slope}}{100}$	Resistance dependent on slope
Curve resistance for BG (R_5)	$0.0004WD$	Resistance dependent on degree of curve
Resistance due to starting (R_6)	$0.15W_1 + 0.005W_2$	Resistance dependent on weight
Resistance due to acceleration (R_7)	$0.028aW$	Resistance dependent on weight and acceleration

25.7 Tractive Effort of a Locomotive

The tractive effort of a locomotive is the force that the locomotive can generate for hauling the load. The tractive effort of a locomotive should be enough for it to haul a train at the maximum permissible speed. There are various tractive effort curves available for different locomotives for different speeds, which enable the computation of the value of tractive effort. Tractive effort is generally equal to or a little greater than the hauling capacity of the locomotive. If the tractive effort is much greater than what is required to haul the train, the wheels of the locomotive may slip.

A rough assessment of the tractive effort of different types of locomotives is provided in the following sections.

25.7.1 Steam Locomotive

The tractive effort of a steam locomotive can be calculated by equating the total power generated by the steam engine to the work done by the driving wheels.

Assume P to be the difference in steam pressure between the two sides of the cylinder, A is the area of the piston of the engine, d is the diameter of the piston of the engine, L is the length of the stroke of the engine, D is the diameter of the wheel of the locomotive, and Te is the mean tractive effort of the locomotive. Work done by a two-cylinder steam engine

= 2 × difference in steam pressure × area of the piston × 2 × length of the stroke

$= 2P \times A \times 2L$

$$= 2P \times \frac{(\pi d^2)}{4} \times 2L = \pi P d^2 L \tag{25.12}$$

Work done in one revolution of the driving wheel of the locomotive:

= tractive effort × circumference of the wheel

$$= \text{Te} \times \pi D \tag{25.13}$$

on equating Eqns (25.12) and (25.13),

$$\pi P d^2 L = Te \times \pi D$$

or

$$\text{Te} = \frac{Pd^2 L}{D} \tag{25.14}$$

It is clear from Eqn (25.14) that tractive effort increases with an increase in steam pressure difference and the diameter and length of the piston, but decreases with an increase in the diameter of the driving wheel of the locomotive.

25.7.2 Diesel Locomotive

Tractive effort of a diesel-elective locomotive can be assessed by the following empirical formula.

$$\text{Te} = \frac{308 \times \text{RHP}}{V} \text{ (kg)} \tag{25.15}$$

where Te is the tractive effort of a diesel-electric locomotive, RHP is the rated horsepower of the engine, and V is the velocity in km/h.

25.7.3 Electric Locomotive

The tractive effort of an electric locomotive varies inversely with the power of speed. The empirical formulae for calculating the approximate value of tractive effort are as follows.

For an dc electric locomotive: Te = a/V^3 (25.16)

For an ac electric locomotive: Te = a/V^5 (25.17)

where a is a constant depending upon the various characteristics of the locomotive.

The important characteristics of three types of tractions are compared in Table 25.2.

Table 25.2 Comparison of steam, diesel and electric traction

Characteristics	*Steam locomotive*	*Diesel locomotive*	*Electric locomotive*
Design characteristics			
Source of energy and basic design characteristics	Coal or oil is burnt to generate steam; a steam engine converts the heat energy of the steam into the rotary energy of the moving wheels.	Diesel oil is used for the generation of power with the help of a diesel engine, the generated power is transmitted by means of a mechanical, hydraulic, or electrical transmission system for propelling the wheels.	Electric energy is supplied from a stationary prime mover, which is converted into mechanical energy for propelling the wheels.
Simplicity of design	The design of the engine is simple. The engine itself is heavy and bulky.	The design is not as simple and compact, the engine weighs less.	The design is complicated but the weight is comparatively low.
Tractive effort	Tractive effort is low because torque is not uniform.	Tractive effort is higher because torque is uniform.	An even higher tractive effort is obtainable.
Adhesion (ratio of tractive effort to weight on wheels, beyond which slipping occurs)	0.20–0.25 because torque is not uniform.	0.25 for electric transmission, 0.33 for hydraulic transmission.	0.25 dc 0.33 ac
Ratio of horse power and weight	75 kg per horsepower	45 kg per horsepower	25 kg per horsepower
Overload capacity	10%–25% overload capacity.	Only 6%–10% overload capacity, which is the overload capacity of the diesel engine.	Over 50% overload capacity, as energy is drawn from an outside source.
Thermal efficiency	About 7%	About 25%	About 90%
Technical experience on Indian Railways	Simple machinery, over hundred years of experience.	More complicated machinery, very limited experience in our country.	Some experience on 1500-V dc systems, experience being acquired on 25-kV ac systems.

(*contd*)

Table 25.2 (*contd*)

Characteristics	*Steam locomotive*	*Diesel locomotive*	*Electric locomotive*
Cost of locomotive	About Rs 5 million	About Rs 15 million	About Rs 18 million
Reversing arrangement	A steam locomotive requires a turntable for reversing its direction.	Reversing of engine is not required. Only the driver and guard have to change their positions.	Reversing of locomotive is not required.
Life of locomotive	About 40 years	About 30 years	Over 30 years
Utilization of power	Fuel is consumed from the moment it is lighted, whether the locomotive is in use or not.	There is no wastage of power when idle if the engine has been switched off.	There is no wastage of power when idle.
Operational characteristics			
Requirement of staff for operation	One driver and two firemen	One driver	One driver
Smoke and fire	Both fire and smoke present.	No fire and little smoke.	No smoke and no fire.
Promptness of service	Takes time for igniting coal and raising enough steam for the engine to start.	Service is readily available.	Ready service without any wastage of time.
Importance of driving skill	Driving skill is important because the driver is required to control each regulating factor separately.	There is not much variance in the regulating factor and so the driver's skill is not important.	Driving is simpler and normal driving skills are sufficient.
Normal working hours	About 12 hours a day	About 21 hours a day	About 21 hours a day
Monthly kilometrage	3500 km/month	9000 km/month	10,000 km/month

(*contd*)

Table 25.2 (*contd*)

Characteristics	*Steam locomotive*	*Diesel locomotive*	*Electric locomotive*
Speeds	Only low speeds are possible; on gradients, speed gets reduced further.	Higher speeds can be achieved; even on gradients, better speeds possible.	Very high speeds; can negotiate steep grades because of high are overload capacity.
Rate of acceleration	Very low	Better	Best
Flexibility in haulage	Can haul only a limited number of coaches to ensure the economic utilization of power.	Can haul a greater number of coaches.	Can haul a large number of coaches.
Condition of track	The track gets damaged due to hammer blow action.	No such damage is caused.	Movement is smooth and there is no damage.
Shed arrangement and time required for service	Shed should have arrangement for turning. General service and boiler maintenance require about 70 hours per month.	Shed is simpler than for a steam locomotive. Maintenance requires about 20 hours a month.	Shed is simple like the diesel ones. Maintenance required is about 4 hours a month.
Transport of fuel	Carries its own fuel supply of water and coal, this consumes a lot of power.	The quantity of oil required is about one-eighth that of coal; cost of transport of fuel is much lower.	Does not require fuel. Overhead electric lines are required for power transmission.
Fuelling points	Intermediate fuelling points required for replenishing the supply of coal and water.	Intermediate fuelling points required for filling diesel oil.	No intermediate fuelling points are required.
Repairs and renewals	Frequent.	Comparatively less.	Minimum.
Suitability	▸ Wherever traffic density is not heavy.	▸ For heavy traffic.	▸ For heavy loads and on gradients. For underground railways.

(*contd*)

Table 25.2 (*contd*)

Characteristics	*Steam locomotive*	*Diesel locomotive*	*Electric locomotive*
	▸ Wherever coal is available at cheap rates.	▸ As an intermediate stage between steam operation and electric traction.	▸ For high speed.
	▸ Wherever water is available.	▸ As intermediate traction.	▸ For suburban traffic and for quick acceleration/deceleration.
Future prospects	▸ Steam locomotives have been phased out on IR.	▸ Bright prospects; more diesel locomotives are being procured.	▸ Best prospects. An increasing number of electric locomotives are being procured.

25.8 Hauling Power of a Locomotive

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

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

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

Example 25.2 Calculate the maximum permissible load that a BG locomotive with three pairs of driving wheels bearing an axle load of 22 t each can pull on a straight level track at a speed of 80 km/h. Also calculate the reduction in speed if the train has to run on a rising gradient of 1 in 200. What would be the further reduction in speed if the train has to negotiate a 4° curve on the rising gradient? Assume the coefficient of friction to be 0.2.

Solution

(a) Hauling power of the locomotive = number of pairs of driving wheels × wt exerted on each pair × coefficient of friction = 3 × 22 × 0.2 = 13.2 t

(b) The total resistance negotiated by the train on a straight level track at a speed of 80 km/h:

R = Resistance due to friction + resistance due to wave action and track irregularities + resistance due to wind

$= 0.0016W + 0.00008WV + 0.0000006WV^2$

Substituting the value of V = 80 km/h

$R = 0.01184W$

Assuming total resistance = hauling power,

$W \times 0.01184 = 13.2$ t

or

$$W = \frac{13.2}{0.01184} = 1114.86\,\text{t} \quad \text{Approx. } 1115\,\text{t}$$

(c) On a gradient of 1 in 200, there will be an additional resistance due to gradient equal to W × % of slope. Since hauling power = total resistance,

$$13.2 = 0.0016W + 0.00008WV + 0.0000006WV^2 + W\frac{0.5}{100}$$

$$= W(0.0016 + 0.00008V + 0.0000006V^2 + 0.005)$$

Since W = 1114.8 t,

$$13.2 = 1114.8\,(0.0016 + 0.000008V + 0.0000006V^2)$$

On solving the equation further,

$V = 48.13$ km/h

Reduction in speed = 80 – 48.13 = 31.87 km/h = 32 km/h

(d) On a curve of 4° on a rising gradient of 1 in 200, curve resistance will be equal to

$R = 0.0004 \times$ degree of curve × wt

$= 0.0004 \times 4 \times W = 0.0016W$

Hauling power of locomotive = total resistance. Therefore,

$13.2 = 0.0016W + 0.00008WV + 0.0000006WV^2 + 0.005W + 0.0016W$

By substituting the value of $W = 1114.8$ t in the equation and solving further,

$V = 43.68$ km/h

Further reduction in speed = 48.13 – 43.68 = 4.45 km/h. Therefore,

Maximum permissible train load = 1115 t

Reduction in speed due to rising gradient = 31.87 t

Further reduction in speed due to curvature = 4.45 km/h

Example 25.3 Compute the steepest gradient that a train of 20 wagons and a locomotive can negotiate given the following data: weight of each wagon = 20 t, weight of locomotive = 150 t, tractive effort of locomotive = 15 t, rolling resistance of locomotive = 3 kg/t, rolling resistance of wagon = 2.5 kg/t, speed of the train = 60 km/h.

Solution

(a) Rolling resistance due to wagons = rolling resistance of wagon × weight of wagon × number of wagons

$= 2.5 \times 20 \times 20 = 1000$ kg = 1 t

(b) Rolling resistance due to locomotive

= rolling resistance of locomotive × wt of locomotive

$= 3 \times 150 = 450$ kg = 0.45 t

(c) Total rolling resistance = rolling resistance due to wagons + rolling resistance due to locomotive = 1.00 + 0.45 t = 1.45 t [resistance due to friction]

(d) Total weight of train = weight of all wagons + wt of locomotive

$= 20 \times 20 + 150 = 550$ t

(e) Total train resistance = rolling resistance + resistance dependent on speed + resistance due to wind + resistance due to gradient

$= 1.45 + 0.00008WV + 0.0000006WV^2 + Wx/100$

$= 1.45 + 0.00008 \times 550 \times 60 + 0.0000006 \times 550 \times 60^2 + (550x/100)$

$= 1.45 + 2.64 + 1.19 + (550x/100) = 5.28 + (550x/100)$

where x is the gradient in 100.

(f) Tractive effort of locomotive = Total train resistance

$15 = 5.28 + (550x/100)$

or

$x = 1.7676$ in 100

= 1 in 56

Therefore, the steepest gradient that the train will be able to negotiate is 1 in 56.

Example 25.4 Calculate the maximum permissible train load that can be pulled by a locomotive with four pairs of driving wheels with an axle load of 28.42 t each on a BG track with a ruling gradient of 1 in 200 and a maximum curvature of 3°, travelling at a speed of 48.3 km/h. Take the coefficient of friction to be 0.2.

Solution

(a) Hauling capacity of locomotive

= no. of pairs of driving wheels × axle load × coefficient of friction

= 4 × 28.42 × 0.2 = 22.736 t

(b) Total resistance of train = resistance due to friction + resistance due to speed + resistance due to wind + resistance due to gradient + resistance due to curve

$= 0.0016W + 0.00008WV + 0.0000006WV^2 + W(1/g) + 0.0004WD$

$= 0.0016W + 0.00008W \times 48.3 + 0.0000006W \times (48.3)^2 + W \times (1/200) + 0.0004 \times W \times 3$

(c) Hauling capacity = total resistance

$22.73 = 0.01306W$

or

$W = 1740$ t

Therefore, the maximum weight of the train is 1740 t.

Summary

There are various types of resistances or forces that oppose the movement of a train on a track. These resistances may be due to the atmosphere, track condition, gradient, curvature, or any other factor. The tractive effort of a locomotive should be sufficient to overcome these resistances so that the desired speed can be maintained. Steam locomotives have gradually been replaced with diesel and electric locomotives on Indian Railways. There are numerous advantages of electric traction over steam and diesel traction.

Review Questions

1. Differentiate between the hauling capacity and the tractive effort of a locomotive.
2. (a) A BG locomotive has three pairs of driving wheels with an axle load of 20 t. If this locomotive is running at a speed of 120 km/h, what is the train weight in t that the locomotive can pull on a straight level track?

   (b) What is the train weight that the same locomotive will be able to haul on a 2° curve and a 1 in 100 gradient?
3. (a) List and explain the various resistances that a locomotive in motion has to overcome.

   (b) Determine the maximum permissible train load that a locomotive with four pairs of driving wheels of a 22.86 t axle load each can pull on a level broad gauge track at a speed of 90 km/h. Also determine the reduced speed of the train if it has to ascend a gradient of 1 in 200 with the same train load.

(Assume the hauling capacity of the locomotive to be one-sixth of the load on the driving wheels).

4. What are the requirements of a locomotive? Briefly describe the merits of the different types of traction commonly used in India.
5. A train with 20 wagons, each weighing 18 t, is supposed to run at a speed of 50 km/h. The tractive effort of a 2-8-2 locomotive with a 22.5 t load on each driving axle is 15 t. The weight of the locomotive is 120 t. The rolling resistance of the wagons and locomotive are 2.5 kg/t and 3.5 kg/t, respectively. The resistance, which depends upon the speed, is computed to be 2.65 t. Find out the steepest gradient for these conditions.
6. Discuss how the hauling capacity of a locomotive is worked out. Compute the steepest gradient that a train of 20 wagons and a locomotive can traverse. Use the following data: weight of each wagon = 20 t, weight of locomotive (with tender) = 150 t, tractive effort of locomotive = 15 t, rolling resistance of wagons = 2.5 kg/t, speed of the train = 60 km/h.
7. What will be the gradient for a BG track when the gradient resistance together with curve resistance due to a 3° curve is equal to the resistance due to ruling gradient of 1 in 200? What would be the resistance when an 8° curve is provided on an MG line and a train with a total weight of 914.85 t is passing over it.
8. What resistances does a locomotive have to overcome for hauling a train in hilly terrains? A goods train with 80 wagons weighing 30 t each is to run at a speed of 50 km/h, while ascending a 0.25% gradient with 2° curves. The train is hauled by a 2-8-4 locomotive with 18.5 t load on each driving axle. Find out whether the locomotive will be able to haul the load at the desired speed. Assume the coefficient of rail–wheel friction to be 0.2.
9. Name the different train resistances that a locomotive has to overcome in hauling a train under adverse circumstances. Explain the factors that would affect speed-dependent resistances. What do you understand by gradient compensation on curved alignment?
10. Compare the various characteristics of steam, diesel and electric traction.

Review Questions (# page - 449)

2. (a) A BG locomotive has three pairs of driving wheels with an axle load of 20 Ton. If this locomotive is running at a speed of 120 km/h, what is the train weight in Ton that the locomotive can pull on a straight level track?

(b) What is the train weight that the same locomotive will be able to haul on a 2° curve and a 1 in 100 gradient?

Solution:

(a)

Hauling power = number of pairs of the driving wheel x wt. exerted on each pair x coefficient of friction

= 3 x 20 x 0.2 (assumed)

= 12 ton

The total resistance negotiated by the train on a straight level of track at a speed of 120 km/h:

$R = 0.0016W + 0.00008WV + 0.0000006WV^2$

$= 0.0016W + 0.00008W \times 120 + 0.0000006W \times 120^2$

$= 0.01984W$

Since, Total Resistance = Hauling Power

$0.01984W = 12$

$W = 12/0.01984$

$W = 604.8387$ ton = 605 ton (approx.)

Means, the more velocity the less weight

(b)

On a gradient of 1 in 100; resistance = $W \times 1/100 = 0.01W$

On a 2° curve; resistance = $0.0004 \times 2 \times W = 0.0008W$

Since, Total Resistance = Hauling Power

$0.0198W + 0.01W + 0.0008W = 12$

$0.0306W = 12$

$W = 12/0.0306$

$W = 392.1568627$ Ton = 390 Ton (approx.)

3. (b) Determine the maximum permissible train load that a locomotive with four pairs of driving wheels of a 22.86 t axle load each can pull on a level broad gauge track at a speed of 90 km/h. Also determine the reduced speed of the train if it has to ascend a gradient of 1 in 200 with the same train load (Assume the hauling capacity of the locomotive to be one-sixth of the load on the driving wheels).

Solution:

Hauling Capacity = 1/6 th of load on driving wheel
= 1/6 th of (22.86 x 4)
= 15.24 ton

The total resistance negotiated by the train on a straight level of track at a speed of 90 km/h:

$R = 0.0016W + 0.00008WV + 0.0000006WV^2$
$= 0.0016W + 0.00008W \times 90 + 0.0000006W \times 90^2$
$= 0.01366W$

Since, Total Resistance = Hauling Power
$0.01366W = 15.24$
$W = 15.24/0.01366$
$W = 1115.666179$ ton = 1115 ton (approx.)

if it has to ascend a gradient of 1 in 200 with the same train load;
resistance = $W \times 1/200 = 0.005W$

so, Total Resistance = Hauling Power
$0.0016W + 0.00008WV + 0.0000006WV^2 + 0.005W = 15.24$
substituting, W = 1115 ton
V = 88.35 km/h (Ans.)

5. A train with 20 wagons, each weighing 18 t, is supposed to run at a speed of 50 km/h. The tractive effort of a 2-8-2 locomotive with a 22.5 t load on each driving axle is 15 t. The weight of the locomotive is 120 t. The rolling resistance of the wagons and locomotive are 2.5 kg/t and 3.5 kg/t, respectively. The resistance, which depends upon the speed, is computed to be 2.65 t. Find out the steepest gradient for these conditions.

Note: Under the Whyte notation for the classification of steam locomotives, 2-8-2 represents the wheel arrangement of two leading wheels on one axle, usually in a leading truck, eight powered and coupled driving wheels on four axles and two trailing wheels on one axle, usually in a trailing truck

Solution:

Total rolling resistance = rolling resistance due to (wagons + locomotive)
= 2.5 kg/t x 20 x 18 + 3.5 kg/t x 120
= 1320 kg = 1.32 ton

Total weight of the train = weight of all wagons + weight of locomotive
= 20 x 18 + 120 = 480 ton

Total train resistance = rolling resistance + resistance dependent on speed + resistance due to wind + resistance due to gradient
$= 1.32 + 0.00008WV + 0.0000006WV^2 + W \times 1/x$

Since, Tractive effort of locomotive = Total train resistance
$15 = 1.32 + 0.00008WV + 0.0000006WV^2 + W \times 1/x$

Substituting, V = 50 km/h, W = 480 ton
$x = 43.47826087$

Therefore, the steepest gradient the train will be able to negotiate is 1 in 43.48

6. Compute the steepest gradient that a train of 20 wagons and a locomotive can traverse. Use the following data: weight of each wagon = 20 t, weight of locomotive (with tender) = 150 t, tractive effort of locomotive = 15 t, rolling resistance of wagons = 2.5 kg/t, speed of the train = 60 km/h.

Solution:

Total rolling resistance = rolling resistance due to (wagons + locomotive)
= 2.5 kg/t x 20 x 20 + 3 kg/t x 150 (assumed)
= 1450 kg = 1.45 ton

Total weight of the train = weight of all wagons + weight of locomotive
= 20 x 20 + 150 = 550 ton

Total train resistance = rolling resistance + resistance dependent on speed + resistance due to wind + resistance due to gradient

$= 1.45 + 0.00008WV + 0.0000006WV^2 + W \times 1/x$

Since, Tractive effort of locomotive = Total train resistance

$15 = 1.45 + 0.00008WV + 0.0000006WV^2 + W \times 1/x$

Substituting, V = 60 km/h, W = 550 ton

$x = 56.5$

Therefore, the steepest gradient the train will be able to negotiate is I in 56.5

7. What will be the gradient for a BG track when the gradient resistance together with curve resistance due to a 3° curve is equal to the resistance due to ruling gradient of 1 in 200? What would be the resistance when an 8° curve is provided on an MG line and a train with a total weight of 914.85 t is passing over it.

Solution:

For BG track,

$W \times 1/x + 0.0004WD = W \times 1/200$

$1/x + 0.0004 \times 3 = 1/200$

$x = 263.1578947$

therefore, the steepest gradient the train will be able to negotiate is 1 in 263

Train resistance on MG track $= 0.0003WD$

$= 0.0003 \times 914.85 \times 8$

$= 2.19564$ ton

Therefore, the resistance when an 8° curve is provided on an MG line and a train with a total weight of 914.85 t is passing over it is 2.2 ton

8. A goods train with 80 wagons weighing 30 t each is to run at a speed of 50 km/h, while ascending a 0.25% gradient with 2° curves. The train is hauled by a 2-8-4 locomotive with 18.5 t load on each driving axle. Find out whether the locomotive will be able to haul the load at the desired speed. Assume the coefficient of rail–wheel friction to be 0.2.

Note: Under the Whyte notation, a 2-8-4 is a steam locomotive that has one unpowered leading axle, usually in a leading truck, followed by four powered and coupled driving axles, and two unpowered trailing axles, usually mounted in a bogie.

Solution:

Total weight of the train, W = weight of wagons + weight of locomotive
= 30 x 80 + 18.5 x 4
= 2474 ton

Tractive force / Hauling capacity = 4 x 18.5 x 0.2
= 14.8 ton

The total resistance negotiated by the train on a straight level of BG track:

$R = 0.0016W + 0.00008WV + 0.0000006WV^2 + W \times 0.25\% + 0.0004WD$

$R = 3.9584 + 0.19792V + 0.0014844V^2 + 6.185 + 1.9792$

$R = 12.1222 + 0.19792V + 0.0014844V^2$

We know that, Total resistance = Hauling capacity

$12.1222 + 0.19792V + 0.0014844V^2 = 14.8$

$V = 12.38 \text{ km/h} < 50 \text{ km/h}$

So, the locomotive will not be able to haul the train at the desired speed.

Week-(14)

MD Ehasan Kabir

CHAPTER
2

Railway Track Gauge

Introduction

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 as shown in Fig. 2.1.

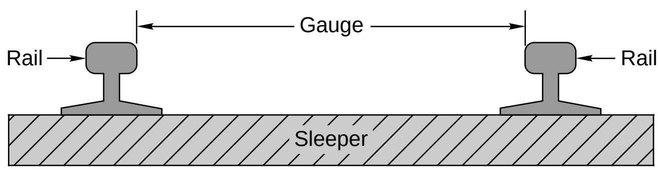


Fig. 2.1 Gauge

In European countries, the gauge is measured between the inner faces of the two rails at a point 14 mm below the top of the rail. This chapter describes the different gauge widths prevalent in India and other countries. It also discusses the problems and implications of a multiple-gauge system as adopted in India.

2.1 Gauges on World Railways

Various gauges have been adopted by different railways in the world due to historical and other considerations. In British Railways, a gauge of 1525 mm (5 feet) was initially adopted, but the wheel flanges at that time were on the outside of the rails. Subsequently, in order to guide the wheels better, the flanges were made inside the rails. The gauge then became 1435 mm (4′ 8.5″), as at that time the width of the rail at the top was 45 mm (1.75″). The 1435-mm gauge became the standard gauge in most European Railways. The approximate proportions of various gauges on world railways are given in Table 2.1.

Table 2.1 Various gauges on world railways

Type of gauge	*Gauge (mm)*	*Gauge (feet)*	*% of total length*	*Countries*
Standard gauge	1435	4′ 8.5″	62	England, USA, Canada, Turkey, Persia, and China

(*contd*)

Table 2.1 (*contd*)

Type of gauge	*Gauge (mm)*	*Gauge (feet)*	*% of total length*	*Countries*
Broad gauge	1676	5′6″	6	India, Pakistan, Ceylon, Brazil, Argentina
Broad gauge	1524	5′0″	9	Russia, Finland
Cape gauge	1067	3′6″	8	Africa, Japan, Java, Australia, and New Zealand
Metre gauge	1000	3′3.5″	9	India, France, Switzerland, and Argentina
23 various other gauges	Different gauges	Different gauges	6	Various countries

2.2 Different Gauges on Indian Railways

The East India Company intended to adopt the standard gauge of 1435 mm in India also. This proposal was, however, challenged by Mr W. Simms, Consulting Engineer to the Government of India, who recommended a wider gauge of 1676 mm (5′6″). The Court of Directors of the East India Company decided to adopt Mr Simms's recommendation and 5′6″ finally became the Indian standard gauge. In 1871, the Government of India wanted to construct cheaper railways for the development of the country and the 1000-mm metre gauge was introduced. In due course of time, two more gauges with widths of 762 mm (2′6″) and 610 mm (2′0″) were introduced for thinly populated areas, mountain railways, and other miscellaneous purposes.

The details of the various gauges existing on Indian Railways are given in Table 2.2.

Table 2.2 Various gauges on Indian Railways

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

2.3 Choice of Gauge

The choice of gauge is very limited, as each country has a fixed gauge and all new railway lines are constructed to adhere to the standard gauge. However, the following factors theoretically influence the choice of the gauge.

Cost Considerations

There is only a marginal increase in the cost of the track if a wider gauge is adopted. In this connection, the following points are important.

(a) There is a proportional increase in the cost of acquisition of land, earthwork, rails, sleepers, ballast, and other track items when constructing a wider gauge.
(b) The cost of building bridges, culverts, and tunnels increases only marginally due to a wider gauge.
(c) The cost of constructing station buildings, platforms, staff quarters, level crossings, signals, etc. associated with the railway network is more or less the same for all gauges.
(d) The cost of rolling stock is independent of the gauge of the track for carrying the same volume of traffic.

Traffic Considerations

The volume of traffic depends upon the size of wagons and the speed and hauling capacity of the train.

(a) As a wider gauge can carry larger wagons and coaches, it can theoretically carry more traffic.
(b) A wider gauge has a greater potential at higher speeds, because speed is a function of the diameter of the wheel, which in turn is limited by the width of the gauge.
(c) The type of traction and signalling equipment required are independent of the gauge.

Physical Features of the Country

It is possible to adopt steeper gradients and sharper curves for a narrow gauge as compared to a wider gauge.

Uniformity of Gauge

The existence of a uniform gauge in a country enables smooth, speedy, and efficient operation of trains. Therefore a single gauge should be adopted irrespective of the minor advantages of a wider gauge and the few limitations of a narrower gauge.

2.4 Problems Caused by Change of Gauge

The need for uniformity of gauge has been recognized by all the advanced countries of the world. A number of problems have cropped up in the operation of Indian Railways because of the use of three gauges. The ill effects of change of gauge (more popularly known as *break of gauge*) are numerous; some of these are enumerated here.

Inconvenience to Passengers

Due to change of gauge, passengers have to change trains mid-journey alongwith their luggage, which causes inconvenience such as the following.

(a) Climbing stairs and crossing bridges

(b) Finding seats in the compartments of the later trains
(c) Missing connections with the later trains in case the earlier train is late
(d) Harassment caused by porters
(e) Transporting luggage
(f) Uncertainty and delay in reaching the destination

Difficulty in Trans-shipment of Goods

Goods have to be trans-shipped at the point where the change of gauge takes place. This causes the following problems.

(a) Damage to goods during trans-shipment.
(b) Considerable delay in receipt of goods at the destination.
(c) Theft or misplacement of goods during trans-shipment and the subsequent claims.
(d) Non-availability of adequate and specialized trans-shipment labour and staff, particularly during strikes.

Inefficient Use of Rolling Stock

As wagons have to move empty in the direction of the trans-shipment point, they are not fully utilized. Similarly, idle wagons of one gauge cannot be moved on another gauge.

Hindrance to Fast Movement of Goods and Passenger Traffic

Due to change in the gauge, traffic cannot move fast which becomes a major problem particularly during emergencies such as war, floods, and accidents.

Additional Facilities at Stations and Yards

(a) Costly sheds and additional facilities need to be provided for handling the large volume of goods at trans-shipment points.
(b) Duplicate equipment and facilities such as yards and platforms need to be provided for both gauges at trans-shipment points.

Difficulties in Balanced Economic Growth

The difference in gauge also leads unbalanced economic growth. This happens because industries set up near MG/NG stations cannot send their goods economically and efficiently to areas being served by BG stations.

Difficulties in Future Gauge Conversion Projects

Gauge conversion is quite difficult, as it requires enormous effort to widen existing tracks. Widening the gauge involves heavy civil engineering work such as widening of the embankment, the bridges and tunnels, as well as the tracks; additionally, a wider rolling stock is also required. During the gauge conversion period, there are operational problems as well since the traffic has to be slowed down and even suspended for a certain period is order to execute the work.

2.5 Uni-gauge Policy of Indian Railways

The problems caused by a multi-gauge system in a country have been discussed in the previous section. The multi-gauge system is not only costly and cumbersome but also causes serious bottlenecks in the operation of the Railways and hinders the balanced development of the country. Indian Railways therefore took the bold decision in 1992 of getting rid of the multi-gauge system and following the uni-gauge policy of adopting the broad gauge (1676 mm) uniformly.

2.5.1 Benefits of Adopting BG (1676 mm) as the Uniform Gauge

The uni-gauge system will be highly beneficial to rail users, the railway administration, as well as to the nation as described below.

No Transport Bottlenecks

There will be no transport bottlenecks after a uniform gauge is adopted and this will lead to improved operational efficiency resulting in fast movement of goods and passengers.

No Trans-shipment Hazards

There will no hazards of trans-shipment and as such no delays, no damage to goods, no inconvenience to passengers of transfer from one train to another train.

Provisions of Alternate Routes

Through a uni-gauge policy, alternate routes will be available for free movement of traffic and there will be less pressure on the existing BG network. This is expected to result in long-haul road traffic reverting to the railways.

Better Turnround

There will be a better turnround of wagons and locomotives, and their usage will improve the operating ratio of the railway system as a whole. As a result the community will be benefited immensely.

Improved Utilization of Track

There will be improved utilization of tracks and reduction in the operating expenses of the railway.

Balanced Economic Growth

The areas presently served by the MG will receive an additional fillip, leading to the removal of regional disparities and balancing economic growth.

No Multiple Tracking Works

The uni-gauge project will eliminate the need for certain traffic facilities and multiple tracking works, which will offset the cost of gauge conversions to a certain extent.

Better Transport Infrastructure

Some of the areas served by the MG have the potential of becoming highly industrialized; skilled manpower is also available. The uni-gauge policy will help in providing these areas a better transportation infrastructure.

Boosting Investor's Confidence

With the liberalization of the economic policy, the uni-gauge projects of the Indian Railways have come to play a significant role. This will help in boosting the investors' confidence that their goods will be distributed throughout the country in time and without any hindrance. This will also help in setting up industries in areas not yet exploited because of the lack of infrastructure facilities.

2.5.2 Planning of Uni-gauge Projects

The gauge-conversion programme has been accelerated in Indian Railways since 1992. In the eight Plan (1993–97) itself, the progress achieved in gauge-conversion projects in 5 years was more than the total progress made in the last 45 years. The progress of gauge-conversion projects is briefly given in Table 2.3.

Table 2.3 Gauge-conversion projects in India

Year	*Progress in gauge conversion (km)*	*Remarks*
1947–1992	2500	Approx. figure
1993–1997	6897	Actual
1997–1998	847	Actual
1998–1999	693	Actual
1999–2000	260	Actual
2000–2001	92	Actual
2001–2002	211	Actual
2002–2003	830	Actual
2003–2004	854	Actual

2.6 Loading Gauge

The loading gauge represents the maximum width and height to which a rolling stock, namely, a locomotive, coach, or wagon, can be built or loaded. Sometimes, a loading gauge is also used for testing loaded and empty vehicles as per the maximum moving dimensions prescribed for the section. In Indian Railways, the maximum height and width of rolling stock prescribed as per the loading gauge are given in Table 2.4.

Table 2.4 Maximum dimensions of rolling stock on Indian Railways

Gauge	*Maximum height of rolling stock*	*Maximum width of rolling stock*
BG	4140 mm (13′7″)	3250 mm (10′8″)
MG	3455 mm (11′4″)	2745 mm (9′0″)

In order to ensure that the wagons are not overloaded, a physical barrier is made by constructing a structure as per the profile of the loading gauge (see Fig. 2.2). This structure consists of a vertical post with an arm from which a steel arc is suspended from the top. The function of this structure is to ensure that the topmost and the widest portion of the load will clear all structures such as bridges and tunnels, etc. along the route.

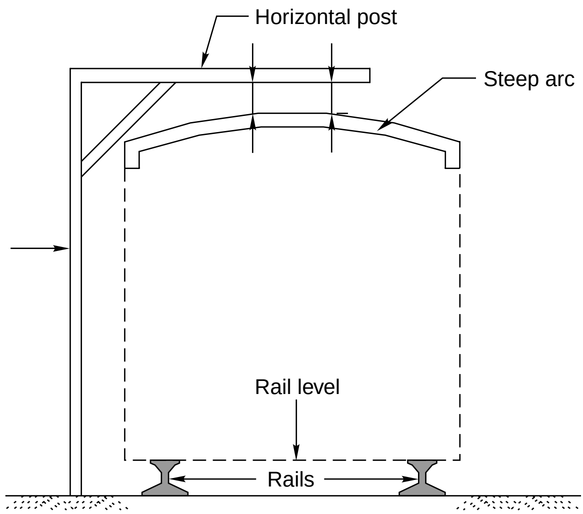


Fig. 2.2 Loading gauge

2.7 Construction Gauge

The construction gauge is decided by adding the necessary clearance to the loading gauge so that vehicles can move safely at the prescribed speed without any infringement. The various fixed structures on railway lines such as bridges, tunnels, and platform sheds are built in accordance with the construction gauge so that the sides and top remain clear of the loading gauge.

Summary

Three types of track gauges have been adopted in Indian Railways. The basic consideration behind the adoption of the metre gauge and narrow gauge was to provide access to undeveloped areas with low cost of construction. The multiple-gauge system has caused many problems and caused serious bottlenecks in the operation of the Railways. The work of gauge conversion has been accelerated on Indian Railways since 1992. The uni-gauge system will be highly beneficial to rail users, the railway administration, and the nation.

Review Questions

1. Define gauge problems with special reference to Indian Railways and bring out the effects of variations in the width of the gauge.

2. Why is it desirable to have, as far as possible, a uniform gauge for the railway network of a country?
3. What is the standard gauge in Indian Railways? State the disadvantages of having a multiple gauge system.
4. List out the various gauges prevailing in India with their gauge widths. What factors govern the selection of a suitable gauge? Discuss.
5. What is the uni-gauge policy of Indian Railways? Describe the benefits of the uni-gauge system.
6. What do you understand by loading gauge? How is it different from the construction gauge?
7. How many gauges exist in Indian Railways? Give their widths and route kilometres.
8. Write short notes on the following.
   (a) Break of gauge
   (b) Standard gauge
   (c) Cape gauge
   (d) Metre gauge

CHAPTER
6

Rails

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. *The finished or complete track of a railway line is known as "Permanent Way"*. To be able to withstand stresses, they are made of high-carbon steel. Standard rail sections, their specifications, and various types of rail defects are discussed in this chapter.

6.1 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.

6.2 Types of Rails

The first rails used were double headed (DH) and made of an I or dumb-bell section (Fig. 6.1). The idea was that once the head wore out during service, the rail could be inverted and reused. Experience, however, showed that while in service the bottom table of the rail was dented to such an extent because of long and continuous contact with the chairs that it was not possible to reuse it. This led to the development of the bull headed (BH) rail, which had an almost similar shape but with more metal in the head to better withstand wear and tear (Fig. 6.2). This rail section had the major drawback that chairs were required for fixing it to the sleepers.

A *flat-footed rail*, also called a *vignole rail* (Fig. 6.3), with an inverted T-type cross section of inverted T- type was, therefore, developed. 1. It could be fixed directly to the sleepers with the help of spikes. Other advantages of the flat-footed rail are that 2. It is a more economical design, 3. Giving greater strength and 4. Providing lateral stability to the track as compared to a BH rail for a given cross-sectional area, 5. No Chairs are required, 6. Less liable to develop kinks, 7. Cost is relatively cheaper than BH (bull headed) or Double headed rails, 8. More uniform load distribution than other types of rails. The flat-footed (FF) rail has been standardized for adoption on Indian Railways.

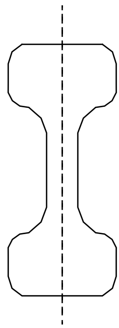


Fig. 6.1 Double headed rail

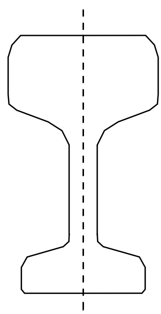


Fig. 6.2 Bull headed rail

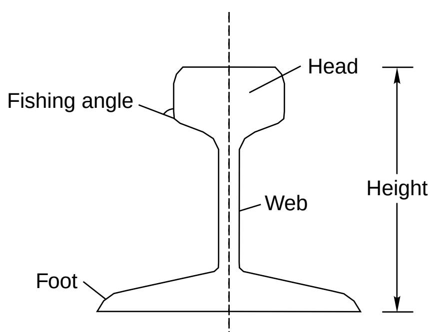


Fig. 6.3 Flat-footed rail

6.3 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.

6.3.1 Standard Rail Section

The rail is designated by its weight per unit length. In FPS units, it is the weight in lbs per yard and in metric units it is in kg per metre. A 52 kg/m rail denotes that it has a weight of 52 kg per metre.

The weight of a rail and its section is decided after considerations such as the following:

(a) Heaviest axle load
(b) Maximum permissible speed
(c) Depth of ballast cushion
(d) Type and spacing of sleepers
(e) Gauge of track
(f) Nature of traffic
(g) Other miscellaneous factors

The standard rail sections in use on Indian Railways are 60 kg, 52 kg, 90 R, 75 R, 60 R and 50 R. The two heavier rail sections, 60 kg and 52 kg, were recently introduced and are designated in metric units. Other rails are designed as per the revised British Standard specifications and are designated in FPS units though their dimensions and weight are now in metric units. In the nomenclature 90 R, 75 R, etc., R stands for revised British specifications.

Every rail rolled has a brand on its web, which is repeated at intervals. As per IRS–T–12–88, the brand marks are as follows:

IRS-52 kg – 710 – TISCO – II 1991 $\rightarrow$ OB

(a) IRS-52-kg: Number of IRS rail section, i.e., 52 kg
(b) 710: Grade of rail section, i.e., 710 or 880
(c) TISCO: Manufacturer's name, e.g., Tata Iron and Steel Co.
(d) II 1991: Month and year of manufacture (February 1991)
(e) $\rightarrow$: An arrow showing the direction of the top of the ingot
(f) OB: Process of steel making, e.g., open hearth basic (OB)

The brand marks on the rails are to be rolled in letters at least 20 mm in size and 1.5 mm in height at intervals of 1.5 to 3.0 m.

The standard rail sections and standard rail length prescribed on Indian Railways are given in Table 6.1.

Table 6.1 Standard rail sections

Gauge	*Rail section*	*Type of section*	*Rail length*
Broad gauge	60 kg/m	UIC	13 m (42 ft as per old standards)
	52 kg/m	IRS	
	90 lb/yd	RBS	
Metre gauge	90 lb/yd	RBS	12 m (39 ft as per old standards), except 90-lb rails, which are of 13 m length
	75 lb/yd	RBS	
	60 lb/yd	RBS	
Narrow gauge	50 lb/yd	RBS	12 m (39 ft as per old standards)

UIC—International Union of Railways, IRS—Indian Railway Standard, RBS—Revised British Standard.

Detailed dimensions of standard rail sections are shown in Fig. 6.4 and Table 6.2.

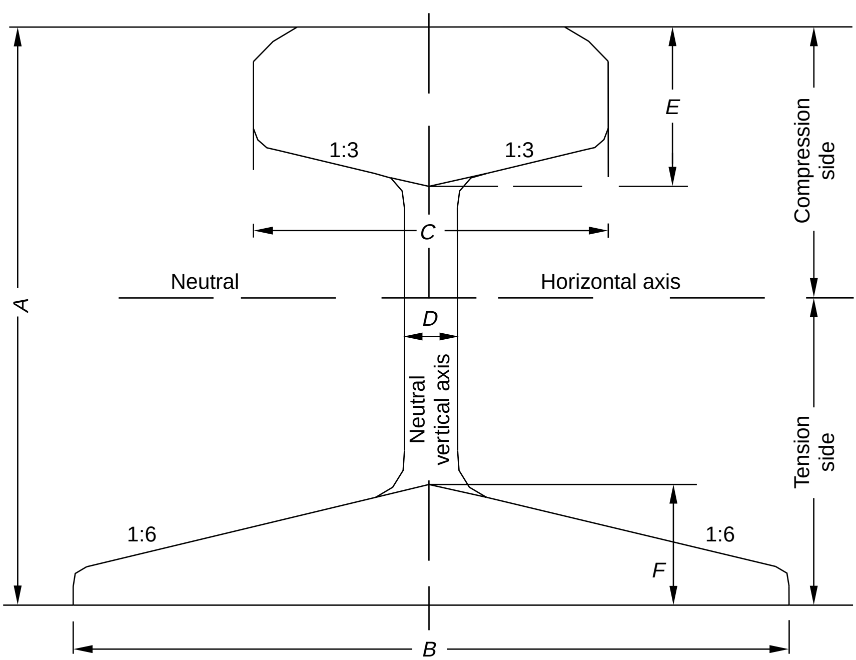


Fig. 6.4 Standard flat-footed rail section

Table 6.2 Details of standard rail sections

Rail section	*Wt/ metre (kg)*	*Area of section (mm²)*	*Dimensions (mm)*					
			A	*B*	*C*	*D*	*E*	*F*
50 R	24.80	3168	104.8	100.0	52.4	9.9	32.9	15.1
60 R	29.76	3800	114.3	109.5	57.2	11.1	35.7	16.7
75 R	37.13	4737	128.6	122.2	61.9	13.1	39.7	18.7
90 R	44.61	5895	142.9	136.5	66.7	13.9	43.7	20.6
52 kg (IRS)	51.89	6615	156.0	136.0	67.0	15.5	51.0	29.0
60 kg (UIC)	60.34	7686	172.0	150.0	74.3	16.5	51.0	31.5

It may be mentioned here that the 90 R rail section is adequate only for an annual traffic density of about 10 GMT (gross million tonnes per km/annum), speeds of up to 100 kmph, axle loads up to main line (ML) standard, and a service life of about 20–25 years. Realizing to these limitations, the Indian Railways, in the year 1959, designed a heavier rail section of 52 kg/m to meet the requirements of heavier and faster traffic. This rail section was recommended for use on all BG main line routes with future speeds of up to 130 kmph and traffic density of 20–25 GMT. The important dimensions of 52-kg and 60-kg rails are shown in Fig. 6.5.

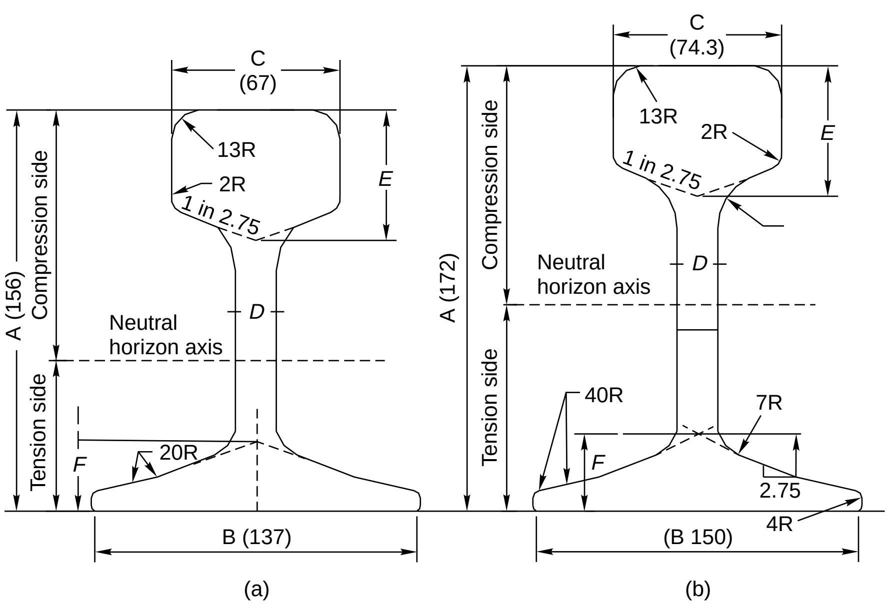


Fig. 6.5 (a) 52-kg rail (b) 60-kg rail

The traffic density on the BG track routes of Indian Railways is increasing very fast. Accordingly, to meet the future requirements of traffic, a new design has been finalized for the 60-kg UIC section rail. The rail section has been designed for speeds of up to 160 kmph and a traffic density of about 35 GMT.

Weight of rails

Though the weights of a rail and its section depend upon various considerations, the heaviest axle load that the rail has to carry plays the most important role. The following is the thumb rule for defining the maximum axle load with relation to the rail section:

Maximum axle load = 560 × sectional weight of rail in lbs per yard or kg per metre

For rails of 90 lbs per yard,

Maximum axle load = 560 × 90 lbs = 50,400 lbs or 22.5 t

For rails of 52 kg per m,

Maximum axle load = 560 × 52 kg = 29.12 t

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.

6.4 Rail Manufacture

The steel used for the manufacture of rails is made by the open hearth or duplex process and should not have a wide variation in its chemical composition. There are essentially four stages of rail manufacturing.

(a) Steel manufacturing process using a basic oxygen/electric arc furnace, including argon rinsing and degassing
(b) Continuous casting of blooms
(c) Rail rolling process including controlled cooling
(d) Rail finishing including eddy current testing, ultrasonic testing, and finishing work

A typical flow chart for the manufacture of rails at the Bhilai steel plant in India is given in Fig. 6.6.

6.4.1 Rail Specifications (IRS-T-12-96)

These specifications apply to flat-bottom symmetrical rails. The quality of steel, manufacturing process, chemical composition, acceptance tests, qualifying criteria, and other technical conditions are given below.

Quality of steel The steel for rails should be of fully killed quality and should conform to the chemical composition and mechanical properties specified in Table 6.3.

Branding and stamping Rails should be hot branded on one side of the web showing relevant details. Each rail should be identified by hot stamping at least once every 4.0 m on the web and should be colour coded in order to distinguish the grade, class, length, and other special requirements.

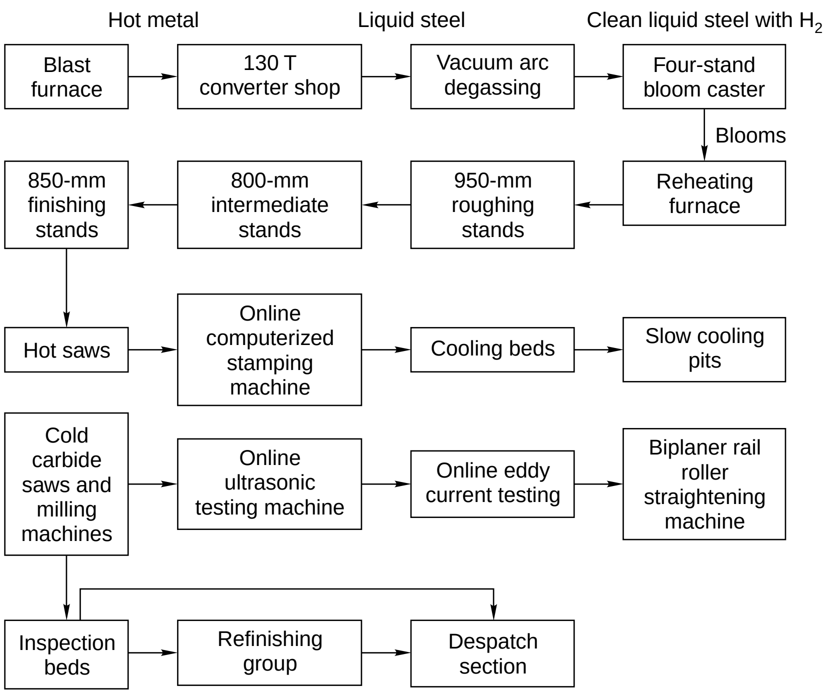


Fig. 6.6 Process of rail manufacture at Bhilai steel plant, India

Table 6.3 Desirable properties of steel for rails

(a) Chemical composition

Grade	*C*	*Mn*	*Si*	*S (max.)*	*P (max.)*	*Al (max.)*	*Liquid hydrogen*
880	0.6–0.8	0.8–1.3	1.3–0.5	0.035*	0.035*	0.02	3.00

* The maximum value for finishing is 0.040.

(b) Mechanical properties

UTS (MPa; min.)	*Elongation % on gauge length = 5.65/S* (min.)*	*Running surface hardness*
880	10.0	Min. 260†

* S = cross-sectional area of piece in mm^2.

† Desirable values.

Rolling quality Each section of the rail should be accurately rolled to its respective template (prepared by the manufacturer and approved by the purchaser or inspecting agency) within permissible tolerance or variations.

Free from defects The rails should be free from all detrimental defects such as cracks of all kinds, flaws, piping, and lack of metal that have an unfavourable effect on the behaviour of rails in service.

Straightness The rail should be absolutely straight. Tolerances for end straightness are very stringent as indicated in Table 6.4.

Table 6.4 Tolerances for end straightness

Straightness	*Tolerance*	
	Class A rails	*Class B rails*
Horizontal	Deviation of 0.5 mm measured as maximum ordinate from the chord of 2.0 m standard sraight edge	Deviation of 0.7 mm measured as maximum ordinate from the chord of 1.5 m standard straight edge
Vertical		
(a) Up sweep	Deviation of 0.4 mm measured as maximum ordinate from the chord of 2.0 m the standard straight edge	Deviation of 0.5 mm measured as maximum ordinate from the chord of 1.5 m standard straight edge
(b) Down sweep	—	—

Permissible Variations in Dimensions

The tolerances allowed in the various parameters of a rail section are given in Table 6.5. These tolerances are subject to the condition that the actual weight determined by weighing the rail piece falls 0.5% below and 1.5% above the calculated weight.

Table 6.5 Permissible variation in dimensions of rails

Item	*Permissible variations in dimensions of rails*
Overall height	+ 0.8 mm to –0.4 mm
Width of head	±0.5 mm (width of head measured 14 mm below the rail top)
Width of flange	±1.0 mm (for sections less than 60 kg/m) + 1.2 mm, –1.0 mm (for sections 60 kg/m and above)
Thickness of web	+ 1.0 mm to –0.5 mm (measured at the point of minimum thickness)
Vertical flange	±1.2 mm (for flange width less than and equal to 150 mm) The base of the rail should be true and flat, but a slight concavity not exceeding 0.40 mm is permissible.
Length of rails	+ 2.0 mm to –10 mm

(*contd*)

Table 6.5 (*contd*)

Item	*Permissible variations in dimensions of rails*
Fishing surfaces	The standard template for the rail fishing surface should not stand away from the contour of the web by more than 1.20 mm and the clearance at the finishing surfaces should not exceed 0.18 mm at any point.
End squareness	The deviation from the square in both horizontal and vertical directions should not exceed 0.60 mm.
Straightness	The maximum permissible deviation should be 0.70 mm, measured as the maximum ordinate on a chord of 1.5 m. Wavy, kinky, and twisted rails should not be accepted.
End straightness	Rails are classified into A and B categories. The details are given in Table 6.4.
Fishbolt holes	Diameter of holes: ±0.70 mm centring and positioning of holes vertically and ±0.70 mm horizontally

Important tests for rails

The following tests are conducted to determine the serviceability of a rail section.

Falling weight or tup test A rail piece of 1.5 m (5 ft) is cut. The rail is supported between the bearers at a prescribed distance. A tup of specified weight (1000 kg for a 90 R rail) is dropped from a height of 7.2 m on the centre of the test piece. The specimen should withstand the blow without any fracture. One falling weight test is done for every cast of 100 metric t. The weight of the tup, distance between the centres of the bearings, and the weight of the drop for different rail sections is given in Table 6.6.

Table 6.6 Details of the tup test

Rail section	*Wt of tup (kg)*	*Distance between centres of bearings (m)*	*Height of drop (m)*
60 kg/m	1270	1.07	8.4
52 kg/m	1270	1.20	7.6
90 R	1000	1.10	7.2
75 R	1000	1.10	6.0

Tensile test A test piece is taken from the head of a rail section and subjected to the tensile test. The tensile strength of the rail should not be less than 72 kg/mm^2, with a minimum elongation of 14% for medium manganese rails and 12% for carbon quality rails. This test is optional and is to be carried out when required by the inspecting official.

Hammer test The foot of the test rail piece is rigidly gripped in a vertical position and the head of the rail is struck with a 4.5 kg hammer. Sufficient number of blows are given till the web bends and the dimensional value of *A* given in Table 6.7 (Fig. 6.7) is achieved. No fracture should occur or a lap be disclosed, otherwise the batch is rejected. This test is no longer required as per IRS/T- 18-88. The values of *A* for various rail sections are listed is Table 6.7.

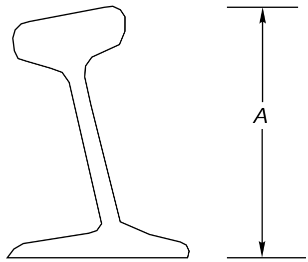


Fig. 6.7 Hammer test

Table 6.7 Values of *A* for different rail sections

Rail section	52 kg/m	90 R	75 R	60 R	50 R
Dimension A in mm	157	144.5	130	117.7	108

6.4.2 Second Quality Rails

Rails that have been rejected either individually or by cast for having failed to fulfil the requirements of IRS specification no. T-12 with regard to chemical composition, or have failed due to defects in surface dimensions and length, may be accepted as second quality rails (T-18) for use in loops and sidings. These second quality rails should conform to the following specifications.

Chemical composition

The chemical composition of the rails should conform to the values given in Table 6.8.

Table 6.8 Required chemical composition for second quality rails*

Element	*% in carbon steel*	*% in medium manganese steel*	*Revised % in medium manganese steel*
Carbon	0.50–0.70	0.40–0.60	0.40–0.65
Manganese	0.60–0.95	0.90–1.45	0.85–1.45
Sulphur	0.06 max.	0.06 max.	0.06 max.
Phosphorus	0.06 max.	0.06 max.	0.06 max.
Silicon	0.03–0.30	0.03–0.30	0.03–0.30

* As per the revised specifications, the percentage of C + Mn should in no case be less than 1.3%. In case carbon exceeds 0.6%, then C + Mn should not exceed 2%.

Surface defects

The following maximum dimensions of the rail surface are considered as minor defects. Rails with these defects are acceptable.

Table of the rail: 0.80 mm
Side of head of the rail: 1.60 mm
Bottom and side of the rail: 1.60 mm

Permissible variations in dimensions

Overall height of the rail: + 1.60 mm, –0.80 mm
Width of head: + 1.20 mm
Thickness of web: + 1.60 mm, –0.60 mm
Length of rail: ±25 mm
Difference in theoretical and actual weight: 1%

Such rails are identified by chamfering a 6-mm-diameter hole at either end, along the centre of the rail and in the middle of the web. These rails are to be used only on loop lines/sidings with a speed restriction of 50 kmph. These rails are painted orange on both sides of the web for a length of 1 m from each end for easy identification.

6.4.3 Third Quality Rails

These are rails that do not conform to the standards set for first or second quality rails but are still fit for use on the railway track. For safety considerations, these are used in industrial sidings where speeds are restricted to 30 kmph for BG and 25 kmph for MG.

Such rails are identified by chamfering a 12-mm-diameter hole at either end, along the centre of the rail and in the middle of the web. A 18 mm marking 'I.U.' is stamped on both end faces of the rail. Third quality rails are painted white on the end face on both sides of the flange for a length of 500 mm from each end for identification.

Third quality rails are manufactured using rejected heats/rails which do not conform to IRS T-12 or T-18 standards with regard to chemical composition, surface defects, dimensions, and straightness.

6.4.4 90 UTS Rails

Indian Railways has mostly been using medium manganese rails with an ultimate tensile strength (UTS) of 72 kg/mm^2 manufactured by the Bhilai steel plant. The service life of 52 kg (72 UTS) rails is only about 350 GMT. On a section with an annual traffic density of about 20 GMT, the renewal cycle is just about 17–18 years, which is rather short as compared to the service life of 50 years of a concrete sleeper. Moreover, such rails wear faster on curves and gradient sections.

In view of the above considerations, Indian Railways has been importing 52-kg and 90 R, 90 UTS rails for some time. These rails have the following main advantages.

1. The service life of 90 UTS rails is about 50% more than that of conventional medium manganese 72 UTS rails.
2. The total GMT that 72 and 90 UTS rails can carry during their primary service life is as follows:

52 kg (72 UTS): 350 GMT
52 kg (90 UTS): 525 GMT
60 kg (90 UTS): 900 GMT

3. 90 UTS rails are more resilient against wear and have a hardness of about 270 BHN (Brinell hardness number) as against that of 220 BHN of medium manganese rails with 72 UTS.
4. The allowable shear stress of 90 UTS rails is much higher, as can be seen from the comparative figures given below:

Rails	*Allowable shear stress*
Medium manganese rails (72 UTS)	18.0 kg/mm^2
Wear-resistant rails (90 UTS)	22.5 kg/mm^2

Studies have shown that the maximum shear stress due to BOX N wagons could be of the order of 20.0 kg/mm^2, which is in excess of the permissible shear stress for medium manganese 72 UTS rails. Therefore, for routes on which BOX N wagons are running, it is desirable to have 90 UTS rails.

End-hardened rails

These are rails with ends that are hardened by oil or water quenching. The wear and tear and end batter of such rails is considerably less.

Head-hardened rails

These are rails with heads that have been hardened by passing them through a thermal treatment plant. The head is hardened for a depth of about 12 mm from the surface. Head hardened rails have a longer service life that extends up to 2–3 times more compared to as ordinary medium manganese rails.

The chemical composition of head-hardened steel (grade 1080) is prescribed as given in Table 6.9.

Table 6.9 Chemical composition of head-hardened rail

Item	*Carbon*	*Manganese*	*Silicon*	*Sulphur*	*Phosphorus*
Limit of values	0.72–0.82	0.75–1.05	0.05–0.30	0.035 max.	0.035 max.

6.5 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 causes of rail wearing are : 1. The impact of moving loads, 2. The effect of the forces of acceleration, deceleration, and braking of wheels, 3. The abrasion due to rail–wheel interaction, 4. The effects of weather conditions such as changes in temperature, snow, and rains, 5. The presence of materials such as sand, 6. 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 railwa 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.

6.5.1 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

6.5.2 Measurement of Wear

Wear on rails can be measured using any of the following methods.

(a) By weighing the rail
(b) By profiling the rail section with the help of lead strips
(c) By profiling the rail section with the help of needles
(d) By using special instruments designed to measure the profile of the rail and record it simultaneously on graph paper

6.5.3 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
(i) Using special alloy to provide high strength

6.5.4 Rail End Batter

The hammering action of moving loads on rail joints batters the rail ends in due course of time. Due to the impact of the blows, the contact surfaces between the rails and sleepers also get worn out, the ballast at places where the sleepers are joined gets shaken up, the fish bolts become loose, and all these factors further worsen the situation, thereby increasing rail end batter.

Rail end batter is measured as the difference between the height of the rail at the end and at a point 30 cm away from the end. If the batter is up to 2 mm, it is classified 'average', and if it is between 2 and 3 mm, it is classified as 'severe'. When rail end batter is excessive and the rail is otherwise alright, the ends can be cropped and the rail reused.

Rail lubricators are provided on sharp curves, where lateral wear is considerable. The function of lubricators is to oil the running face of the outer rail in order to reduce the friction. It has been noticed that this considerably reduces the wear, by up to 50%. There are many mechanical devices that can be attached to the wheels to provide such lubrication. In these mechanical arrangements, the wheels of moving trains normally cause the lubricant to flow on the side of the rail either by the action of the wheels pressing the plunger up and down or by ramps on account of the rails being depressed by wheels. Sometimes the movement of trains also cause lubricants to flow. Based on the principle of the plunger being pressed by moving wheels, P and M type lubricators have been provided on curves in some sections such as the 'Ghat section' of Central Railway and these are working very satisfactorily. For more details on wear, including limit of wear, refer to Chapter 23.

6.6 Other Defects in Rails

Rail wear and the battering of rail ends are the two major defects in rails. However, some other types of defects may also develop in a rail and necessitate its removal in extreme cases. These are described below.

6.6.1 Hogging of rails

Rail ends get hogged due to poor maintenance of the rail joint, yielding formation, loose and faulty fastenings, and other such reasons. Hogging of rails causes the quality of the track to deteriorate. This defect can be remedied by measured shovel packing. (For details, refer to Chapter 20.)

6.6.2 Scabbing of rails

The scabbing of rails occurs due to the falling of patches or chunks of metal from the rail table. Scabbing is generally seen in the shape of an elliptical depression, whose surface reveals a progressive fracture with numerous cracks around it.

6.6.3 Wheel burns

Wheel burns are caused by the slipping of the driving wheel of locomotives on the rail surface. As a consequence, extra heat is generated and the surface of the rail gets affected, resulting in a depression on the rail table. Wheel burns are generally noticed on steep gradients or where there are heavy incidences of braking or near water columns.

6.6.4 Shelling and black spots

Shelling is the progressive horizontal separation of metal that occurs on the gauge side, generally at the upper gauge corner. It is primarily caused by heavy bearing pressure on a small area of contact, which produces heavy internal shear stresses.

Corrugation of rails

Corrugation consists of minute depressions on the surface of rails, varying in shape and size and occurring at irregular intervals. The exact cause of corrugation is not yet known, though many theories have been put forward. *The factors which help in the formation of rail corrugation*, however, are briefly enumerated here.

(a) Metallurgy and age of rails
   (i) High nitrogen content of the rails
   (ii) Effect of oscillation at the time of rolling and straightening of rails.

(b) Physical and environment conditions of track
   (i) Steep gradients
   (ii) Yielding formation
   (iii) Long tunnels
   (iv) Electrified sections

(c) Train operations
   (i) High speeds and high axle loads
   (ii) Starting locations of trains
   (iii) Locations where brakes are applied to stop the train

(d) Atmospheric effects
   (i) High moisture content in the air particularly in coastal areas
   (ii) Presence of sand

Effects of Corrugation:

The corrugation of rails is quite an undesirable feature. When vehicles pass over corrugated rails, a roaring sound is produced, possibly due to the locking of air in the corrugation. This phenomenon is sometimes called 'Roaring of rails'. This unpleasant and excessive noise causes great inconvenience to the passengers. Corrugation also results in the rapid oscillation of rails, which in turn loosens the keys, causes excessive wear to fittings, and disturbs the packing.

Corrugation can be removed by grinding the rail head by a fraction of a millimeter. No method has been standardized on Indian Railways to grind rail surfaces. The problem of corrugation, however, has been tackled in great detail on German Railways, where two types of equipment are normally used for rail grinding.

(i) Hand or motor-driven trollies that move on the rails at slow speeds and grind the individual rails one by one.

(ii) Rail grinding train, which moves at a speed of 30 kmph and grinds both rails simultaneously.

6.7 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.

6.7.1 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.

6.7.2 Classification of Rail Failures

The classification of rail failures on Indian Railways has been codified for easy processing of statistical data. The code is made up of two portions—the first portion consisting of three code letters and the second portion consisting of three or four code digits.

First portion of the code The three code letters make up the first portion and denote the following.

(i) Type of rail being used (O for plain rail and X for points and crossing rails)
(ii) Reasons for withdrawal of rail (F for fractured, C for cracked, and D for defective)
(iii) Probable cause for failure (S for fault of rolling stock, C for excessive corrosion, D for derailment, and O for others)

Second portion of code The second portion of code the consisting of three or four digits gives the following information.

(i) Location of the fracture on the length of the rail (1 for within fish plate limits and 2 for other portions on the rail)
(ii) Position in the rail section from where the failure started (0 for unknown, 1 for within rail head, 2 for surface of rail head, 3 for web, and 4 for foot)
(iii) Direction of crack or fracture (0 to 9)

(iv) Any other information about the fracture, where it is necessary to provide further subdivision. No specific system is recommended for this code.

6.7.3 Metallurgical Investigation

The following types of defective rails should normally be sent for metallurgical investigation.

(i) Rails that have been removed from the track as a result of visual or ultrasonic detection

(ii) Rail failures falling in categories in which cracks or surface defects develop at specified locations.

6.8 Rail Flaw Detection

A defect in a rail which will ultimately lead to the fracture or breakage of the rail is called a *flaw*. From the point of view of the ultimate consequence of the flaw resulting in a fracture, it is necessary to detect these flaws and take timely action to remove them. Rail flaws can be detected either by visual examination of the rail ends or by rail flaw detection equipment.

Visual examination of rail ends In this method, the joint is first opened after removing the fish plates. The rail ends are then cleaned using kerosene oil and visually examined in detail with the help of a magnifying glass for any hair crack, etc. White chalk is sometimes rubbed on the rail ends so as to identify the flaw clearly. A mirror is used to reflect light on the joint in case sufficient light is not available.

Ultrasonic rail flaw detectors Ultrasonic rail flaw detectors (USFDs) have been progressively used in recent years on Indian Railways for the detection of flaws. This method is also known as the non-destructive method of testing rails.

6.8.1 Theory of Ultrasonic Rail Flaw Detectors

Vibration waves of a frequency of more than 20,000 cycles per second are termed as ultrasonic waves. These waves have the property of being able to pass through materials and following the normal principles of light waves of refraction, reflection, and transmission. Whenever there is a change of medium, some of the ultrasonic energy gets reflected and the rest gets transmitted. The amount of energy reflected depends upon the physical properties of the two media. When travelling through steel, if these waves come across air either from the bottom of the steel or from any flaw inside the steel, the reflection is almost 100%. This property has been found most useful for detecting flaws in rails. Thus, when ultrasonic waves are fed from a location on a rail, they pass through the rail metal and are normally reflected only from the foot. However, if a discontinuity exists in the rail metal due to some flaw, the ultrasonic waves get reflected back from the location of the flaw, which can be picked up and the defect located.

Production of ultrasonic waves

There are several methods of producing ultrasonic energy. The most common and simple method of producing ultrasonic frequency is by using '*crystal transducers*', which normally produce ultrasonic waves of a frequency of up to 15 MHz. The crystals generally used for this purpose are made either of quartz or of barium titanate, cut to special size, shape, and dimensions. These crystals have the peculiar property of changing dimensions and generating vibrations in a particular direction when an oscillating electric charge is applied to the crystal faces. Also, when these crystals are made to vibrate, they produce an oscillating electric current. The crystals, as such, have the potential of generating ultrasonic vibrations, as also of converting the waves received after reflection into electric current. They also possess reversible properties.

These crystals are housed in metal holders protected by superior quality Perspex and then termed probes. There are two types of probes used for ultrasonic testing.

Normal probe This probe consists of two semi-cylindrical thin crystals with a vertical separating layer through the crystals and Perspex. These probes transmit ultrasonic waves vertically downwards when put on the rail and are suitable for detecting horizontal or inclined flaws, including bolt hole cracks.

Angle probe In this probe, crystals are mounted on an angular surface capable of transmitting pulses at an outward angle, which may be forward or backward or both, with separate transmitting and receiving crystals. The waves emitted by these probes follow an inclined path and are suited to detect inclined and vertical defects.

Techniques of ultrasonic testing

A number of techniques have been used in ultrasonic testing to suit the design of different equipment. Some of these techniques are the following.

(a) Frequency modulation
(b) Pulse echo
(c) Transmission
(d) Resonance
(e) Acoustic range

Indian Railways uses the frequency modulation and pulse echo techniques and only these are discussed in detail here.

Frequency modulation technique In instruments utilizing frequency modulation ultrasonic waves are created with the help of a probe crystal and transmitted continuously into the rail at rapidly changing frequencies. It is necessary for the rail head to be wet to enable the ultrasonic waves to pass efficiently from the crystal to the rail. The waves that get reflected from the opposite face are received continuously by the crystal. There is interference between the transmitted waves and the reflected waves, which causes resonance. As the frequencies of the transmitted waves are changing constantly, such resonance takes place at regular intervals. When the position of reflection is changed due to a flaw in the metal, the resonance gets affected, which can be easily detected by the operator. Instruments manufactured on this principle such as the Audi-gauge are light, portable, and simple in mechanism. However, these instruments have certain limitations.

(a) Fine vertical cracks are not readily detected because the single vertical probe does not find any surface defect from which it can be reflected.

(b) Cracks wholly below bolt holes are also not detected, as the vibrations are interrupted by the hole.

Pulse echo system In the pulse echo technique, a pulsed ultrasonic beam of very high frequency is produced by a pulse generator and sent in to the rail. At the opposite face, the ultrasonic waves are reflected and the echo is picked up by the crystal transducers. A discontinuity or defect in the rail will also produce the echo. The time interval between the initial pulse and the arrival of the echoes is measured with the help of a cathode ray tube. There may be multiple reflections of the echo but the one arising due to a fault can easily be determined by its relative position and amplitude.

The more sophisticated types of instruments that are based on the pulse echo system are being manufactured by the firm Kraut Kramer at present.

6.8.2 Kraut Kramer Multi Probe Rail Testing Trolley

This is the most common type of equipment used on Indian Railways for detecting flaws in the rail Fig. 6.8. The equipment is fitted on a hand trolley that is carried on the rails. There are two probes: a normal probe and an angle probe, both act independently. The probe material used for the production of ultrasonic waves is barium titanate, which produces and transmits vertical ultrasonic waves of four megacycles frequency through the vertical probe and 2 mega cycles frequency through the angle probe. The cylindrical probe is mounted on a knuckle jointed holder frame and has a renewable bakelite wear plate at the base. As the probe is worked over the rail, the bakelite piece takes the wear completely. The height of the probe above the rail surface can be adjusted in the holder assembly. The normal probe is powerful enough to scan the entire rail depth for defects. It can detect longitudinal discontinuities in the head at the junction of either the web and the foot or the web and the head as well as cracks from bolt holes. It cannot, however, detect vertical cracks. The defects detected by the normal probe are represented on the oscilloscope screen in the form of firm echoes protruding from a base line. Ordinarily, two echoes are visible on the screen, the initial echo due to the partial reflection of the waves from the rail top and the back echo from the bottom of the rail. Any echo between the initial and the back echo with a corresponding reduction in the height of the back echo is termed a *flaw echo* and is indicative of a flaw. The position of the flaw can be known by reading the distance of this intermediate echo from the initial echo, which will be the distance of the flaw from the rail top.

The ultrasonic rail testing trolley can be used without any block protection, but one has to be vigilant about the movement of trains. Progress depends upon the experience and the efficiency of the operator. The work is quite strenuous in nature and a single operator cannot observe the screen continuously for a long time. Work can also not be done during the middle of the day in the summer months because the operator will not be able to pick up the signals clearly. On account of these limitations, the work progresses rather slowly and approximately 2–3 km of rail are covered per day with two operators.

Fig. 6.8 Ultrasonic rail testing trolley

6.8.3 Classification of Rail Flaws

Depending upon the nature and extent of internal flaws, traffic density, and speed on the section, the defects noticed by rail flaw detection methods have been classified into three major categories, i.e., IMR, REM, and OBS.

IMR defects A defect that is serious in nature and can lead to sudden failure is classified as IMR. Immediately after detection, clamped fish plates should be provided for the defective portions and a speed restriction of 30 kmph imposed till the IMR rail is removed by a sound-tested rail piece of not less than 6 m. A watchman should be posted till the clamped fish plates are provided to avoid any mishaps. IMR stands for immediate removal.

REM defects These are the type of defects that warrant early removal of the rail from the track. These defects are marked with red paint. REM stands for remove.

OBS defects These are defects that are not so serious. The rail need not be removed in such cases but should be kept under observation. These defects are marked with yellow paint. OBS stands for observe. OBS defects have been further classified as OBS (E) and OBS (B). An OBS defect located within the fish-plated zone is designated OBS (E). Similarly, an OBS defect on major bridges and up to 100 m on their approaches is designated OBS (B).

In the case of the need-based concept of ultrasonic testing (explained in Section 6.8.6), there are only two types of defects, IMR and OBS. However, if the defects occur at welded joints, they are called IMR (R) and OBS (W) defects.

The actions to be taken upon the detection of defective rails are summarized in Table 6.10.

Table 6.10 Actions to be taken upon the detection of defective rails

Classification of defects	*Action required*	*Speed restriction to be imposed if the required action is delayed*
IMR (red - 3 stars)	Immediate replacement (not later than 3 days)	Impose 30 km/h and depute a watchman till defective part replaced
REM (Red - 2 stars)	Replace within 15 days	Impose 30 km/h if not replaced within 15 days
OBS (E) (red - 1 star)	Replace or end crop within 15 days	Impose 30 km/h if not replaced within 15 days
OBS (B) (Red - 1 star)	Replace within 15 days	Impose 30 km/h if not replaced within 15 days

In the case of OBS rails other than OBS (E) and OBS (D), permanent way inspector (PWI) should observe each OBS location with a magnifying glass and duly record his observations once a month, to see if the crack has developed any further, in which case the same action as for REM defects should be taken. The PWI should maintain sleepers, fittings, and the ballast at such locations in sound condition. The assistant engineer should also test-check some of the OBS locations and record his observations during his monthly push trolley inspection of each section.

6.8.4 Ultrasonic Rail Flaw Testing Car

As the portable ultrasonic rail flaw detector can test only 2–3 km of rails everyday, advanced railways such as German Railways have developed a *rail testing car* that can test a much longer length of track much more effectively. The test car tests the track at a speed of 30 kmph and each of the two rails is tested ultrasonically by means of five probes (0°, ±35°, ±70°) and an airborne sound assembly. The test results are recorded photographically on a tape, a subsequent examination of which can reveal all the flaws. The flaws can then be properly classified. Their position in the track can also be pinpointed with respect to kilometrage to an accuracy of 1 m. This special car tests the track during the day and covers 100–200 km per day. The car covers approximately 20,000 km of track every year on German Railways. The average cost of testing is Rs 300–500 per km of the track. With the present trend in increase in speed, the need for ultrasonic inspection of rails is felt all the more to avoid hazards due to rail fractures, and in this context, the use of the test car on Indian Railways is considered a technical and operational necessity.

6.8.5 Self-propelled Ultrasonic Rail Testing Car

Indian Railways has recently procured a self-propelled ultrasonic rail testing (SPURT) car of make MATRIX-VUR-404 from Sa Matrix Industries, Paris, at a total cost of approximately Rs 25 million, inclusive of ancillary equipment. The MATRIX car is capable of detecting, measuring, recording, and simultaneously analysing the internal defects of rails using a non-destructive method of rail flaw detection. The rail testing car has been designed for simultaneous examination of rails, points, and crossings at a maximum speed of 40 kmph. It consists of the following parts.

(a) An ultrasonic detection lorry
(b) An electronic unit including all circuit transmitters, receivers, selectors, and auxiliaries
(c) Two multi-track recorders installed at either end of the car
(d) A real-time automatic defect analyser

The various components of rail flaw detecting equipment are shown in the schematic diagram in Fig. 6.9. Testing is done using five probes at different angles, which are able to detect rail flaws.

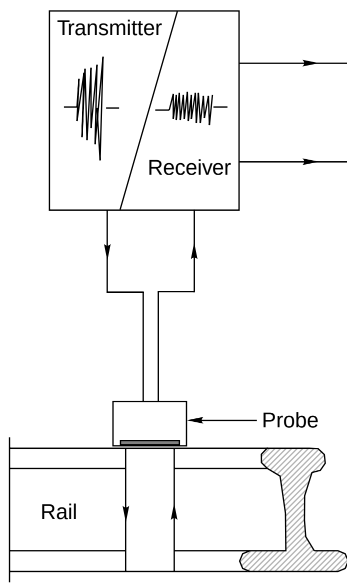


Fig. 6.9 Various components of ultrasonic rail flaw detecting equipment

The SPURT car can detect most rail defects that normally develop under traffic during service. The type of defect, its size, and its position in the rail section is automatically determined. The SPURT car is able to screen the rail section completely in the web and almost completely in the head and the zone of the foot below the web. The flange of the foot and the top corners of the head, however, are not screened. The defects recorded are automatically analysed. The results are given in a synthesized form in a prescribed manner.

It is expected that the SPURT car will be used intensively on Indian Railways and that it will be possible to control rail fractures/failures on Indian Railways to a considerable extent.

6.8.6 Need-based Concept of USFD Testing

Indian Railways has decided to introduce on its system a need-based concept of USFD testing based on a Russian concept. As per the present policy, need-based rail inspection is being progressively introduced on A (not covered by the SPURT car), B, and D routes on Indian Railways. The introduction of this concept will require changing the present classification of defects, frequency of inspection, detection equipment, organization, etc.

The following are the important features of the need-based scheme of USFD testing.

Traffic density and periodicity In the need-based concept, the stipulated frequency of ultrasonic inspection is one after the passage of every 8 GMT, with periodicity varying from 2 to 6 months, depending on the sectional GMT.

Important related parameters The system has been evolved based on the consideration of two important related parameters: permissible condemning defects size and inspection frequency. Other important factors such as microstructure of rail steel and nature and orientation of cracks, have not been taken into consideration.

Defect size Under the concept, a defect size of 12 mm and above in the head and 5 mm and above in the web junction is taken into account for the classification of defects. Therefore, defects sized below 12 mm and 5 mm are allowed to continue in the tracks as unclassified defects. Further, the same size of artificial flaw, i.e., 12 mm, is considered when classifying the weld defect too. Attenuation or absorption of ultrasonic energy is supposed to be more in SKV/AT welded joints due to coarse grain, whereas absorption of energy is less in rail steel. (SKV is a German word meaning short preheating. AT denotes alumino thermit.) Obviously, the specified 60% peak height will not be available in the same grain setting in the case of welds.

Frequency of testing of rails and welds An inspection frequency of 8 GMT has been prescribed for the need-based concept of ultrasonic testing. A higher inspection frequency may be fixed depending upon the incidence of defects. In view of this, whenever the defect generation rate (failures in service and defects detected during USFD inspection) exceeds 1 per km between successive tests in a stretch, the inspection frequency should be doubled in that particular stretch. When calculating the defect generation rate, only rail defects (IMR) or fractures with an apparent origin other than the bolt area and detectable by USFD should be considered.

Testing of rails After the initial testing of rails in the rail manufacturing plant, the first re-test normally need not be done until the rails have covered 15% of their service life in GMT as given in Table 6.11. For rails rolled in April 1999 and later, the test-free period will be 25% instead of 15%.

Table 6.11 Service life of rails

Gauge	*Rail section*	*Assessed GMT service life for T-12-72 UTS rails*	*Assessed GMT service life for T-12-90 UTS rails*
BG	60 kg	550	800
	52 kg	350	525
	90 R	250	375
MG	75 R	150	225
	60 R	125	–

Whenever rails are not tested in the rail manufacturing plant, the test-free period will be applicable, and rail testing will be done at the periodic interval given in Table 6.12 right from the day of its laying in the field. This table gives the frequency of ultrasonic testing after the passage of 8 GMT, subject to a maximum interval of one year.

Table 6.12 Frequency of ultrasonic testing for all BG routes

GMT	*Testing frequency (months)*
Up to 8	12
8 < GMT < 12	9
12 GMT < 16	6
16 < GMT < 24	4
24 GMT < 40	3
> 40	2

In the need-based concept, the actions suggested in Table 6.13 are taken when defective rails are detected.

Table 6.13 Action to be taken after detection of rail/weld defects

Classification	*Painting on both faces of the web*	*Action to be taken*	*Interim action*
IMR/ IMR (W)	Three crosses made with red paint	The flawed portion should be replaced by a sound-tested rail piece of not less than 6 m length within three days of detection	PWI/USFD (ultrasonic flaw detecting officer) shall impose speed restriction of 30 kmph immediately and this to be continued till the flawed rail weld is replaced. He should communicate the location of the flaw to the sectional PWI, who shall ensure that a clamped, joggled fish plate is provided within 24 hrs.
OBS/ OBS (W)	One cross made with red paint	Rail/weld to be provided with clamped, joggled fish plate within three days. PWI/USFD to specifically record his observations of the location in his register in subsequent rounds of testing.	• PWI/USFD to advise sectional PWI within 24 hrs about flaw location. • Keyman to watch during daily patrolling till it is joggled fish plated.

Summary

Various types of rail sections and their specifications have been discussed in this chapter. Flat–footed rails are commonly used on Indian Railways. A rail section may develop different types of defects during its service life. The defect in a rail should immediately be attended to, otherwise it will lead to the failure of the rail. The various types of defects in a rail and the remedial measures to be adopted have been highlighted in this chapter.

Review Questions

1. What are the functions of rails? Name the various types of rails in use. Which one is widely used now? How is the weight of a rail section usually determined?
2. Enumerate the various stresses a rail is subjected to in a track. Describe the nature of contact stresses between the wheel and the rail, distinguishing the cases of new and worn wheels.
3. It is observed that at present tracks, are mostly laid with flat-footed rails. Give reasons for this preference in relation to other types of rail sections.
4. Defects in rails can be divided into the following three ctaegories:
   (a) Defective rail steel
   (b) Surface defects
   (c) Service defects

   Explain these defects clearly.
5. What is meant by wear of rails? Categorize the types of rail wear and enumerate the methods by which wear in rails can be measured.
6. What factors govern the permissible limit of rail wear?
7. Determine the suitable rail section for a locomotive carrying an axle load of 22.5 t. (***Ans***: 90 R)

Week-(15)

MD Ehasan Kabir

CHAPTER
10

Track Fittings and Fastenings

Introduction

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. The important fittings and fastenings commonly used in India are listed in Table 10.1.

Table 10.1 Types of track fittings

Purpose and type	*Details of fittings and fastenings*
Joining rail to rail	Fish plates, combination fish plates, bolts, and nuts
Joining rail to wooden sleepers	Dog spikes, fang bolts, screw spikes, and bearing plates
Joining rail to steel trough sleepers	Loose jaws, keys, and liners
Joining rail to cast iron sleepers	Tie bars and cotters
Elastic fastenings to be used with concrete, steel, and wooden sleepers	Elastic or Pandrol clip, IRN 202 clip, HM fastening, MSI insert, rubber pads, and nylon liners

The number of various fittings and fastenings required per sleeper for ordinary or conventional fastening as well as elastic fastening for different types of sleepers are summarized in Table 10.2.

Table 10.2 Number of fastenings

Type of sleeper	*Ordinary fastenings per sleeper*	*Number*	*Elastic fastening per sleeper*	*Number*
Wooden	Dog spikes or	8	CI bearing plates	2
	Screw spikes	8	Plate screws	8
	Keys for CI bearing plates	4	Pandrol clips	4
			Rubber pads	2

(*contd*)

Table 10.2 (*contd*)

Type of sleeper	*Ordinary fastenings per sleeper*	*Number*	*Elastic fastening per sleeper*	*Number*
Concrete	No ordinary fastening	–	Pandrol clips	4
			Nylon liners	4
			Rubber pads	2
			MCI inserts	4
Steel trough	Keys	4	Modified loose jaws	4
	Loose jaws	4	Pandrol clips	4
			Rubber pads	2
CST-9	Plates	2	Pandrol clips	4
	Tie bar	1	Rubber pads	2
	Cotters	4		
	Keys	4		

All these fittings and fastenings together with other ancillary features, are discussed in this chapter.

10.1 Rail-to-Rail Fastenings

Rail-to-rail fastenings involve the use of fish plates and bolts for joining rails in series. Detailed descriptions of these are given in the following sections.

10.1.1 Fish Plates

The name 'fish plate' derives from the fish-shaped section of this fitting (Fig. 10.1). 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%

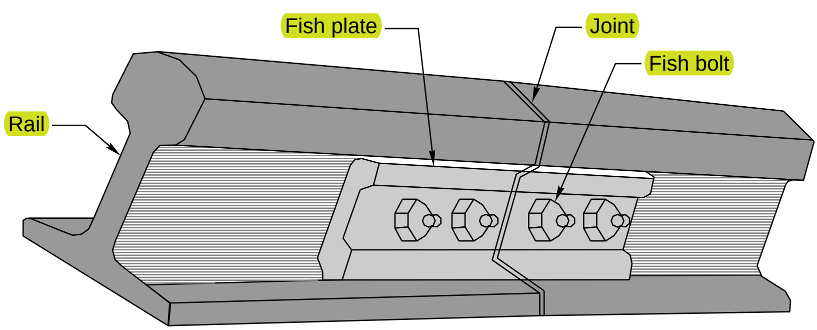


Fig. 10.1 Fish plate

The steel used for fish plates should have a minimum tensile strength of 5.58 to 6.51 t/cm^2 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 as shown in Fig. 10.2. The details of standard fish plates used on Indian Railways for different rail sections are given in Table 10.3.

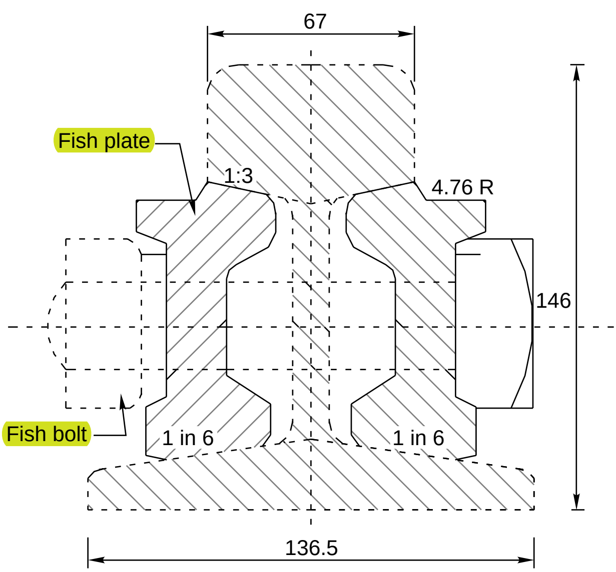


Fig. 10.2 Fish plate for 90 R rails

Table 10.3 Details of standard fish plates

Rail section	*Drawing number*	*Weight per pair (kg)*	*Total length of fish plate [mm (in.)]*	*Length from centre to centre of hole [mm (in.)]*	*Diametre of fish bolt holes (mm)*
52 kg	090 M	28.71	610 (24)	166 (6.5)	27
90 R	071 M	26.11	610 (24)	166 (6.5)	27
90 R	059 M	19.54	460 (18)	114 (4.5)	27
75 R	060 M	13.58	420 (16.5)	102 (4)	27
60 R	961 M	9.98	410 (16)	102 (4)	24
50 R	1898 M	8.31	410 (16)	102 (4)	20

10.1.2 Combination Fish Plates

Combination or junction fish plates (Fig. 10.3) are used to connect rails of two differential sections. These are designed to cover the rail section at either end adequately up to the point in the centre where the rail section changes. Another design feature in these junction fish plates is the elimination of the expansion gap in order to give them more strength. In spite of the varying depths of the combination fish plates used in the fitting of 52 kg/90 R, 90 R/75 R, 75 R/60 R, etc. rail sections, the use of junction fish plates provides a common top table for the two rail sections they join. A uniform system of marking and exact nomenclature is adopted for each junction fish plate for proper identification. Fish plates are marked right in, right out, left in, and left out depending upon their position with respect to the direction from the lighter rail to the heavier rail (as shown in Fig. 10.4). In the case of any difficulty in obtaining a combination fish plate, the following alternate arrangement can be made.

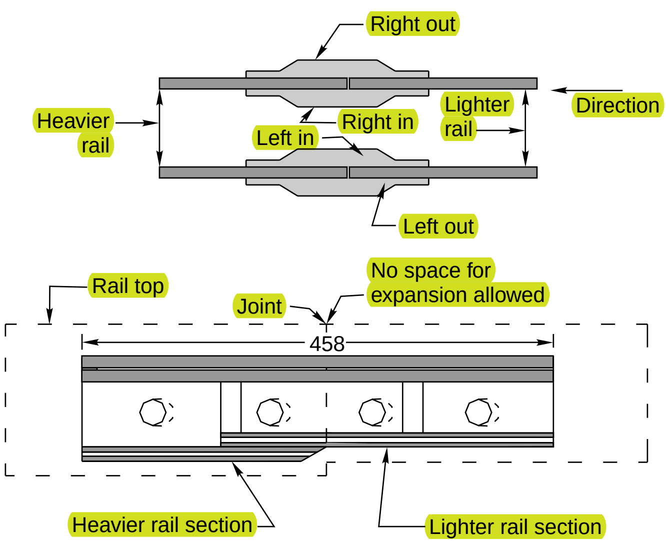


Fig. 10.3 Combination fish plate (dimensions in mm)

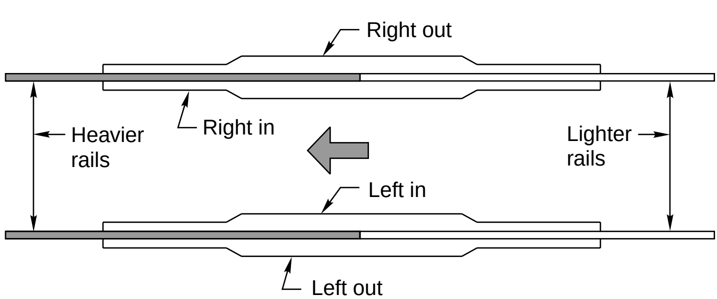


Fig. 10.4 Marking of combination fish plates

1. First the composite rail, normally of a length not less than 4 m, is prepared by welding together two rail pieces of different rail sections.
2. This composite rail piece is then inserted at the joint in lieu of the combination fish plate.
3. Normal fish plates are then used to join the composite rail piece to the rail lengths on either side, which have a rail section identical to that of the composite rail piece.

10.2 Fittings for Wooden Sleepers

Rails are fixed to wooden sleepers with the help of simple types of fastenings such as spikes, screws, and bearing plates.

10.2.1 Dog Spikes

This fastening is named dog spike (Fig. 10.5) because the head of this spike looks like the ear of a dog. Dog spikes are used for fixing rails to wooden sleepers. The number of dog spikes normally used is as follows:

Location	*Number of dog spikes*
• On straight track	2 (1 on either side and duly staggered)
• On curved track	3 (2 outside and 1 inside)
• Joint sleepers, bridges	4 (2 outside and 2 inside)

The dog spike has a 16-mm square section and its length varies depending upon the location at which it is placed, as given in Table 10.4.

Table 10.4 Details of dog spikes

Location of dog spike	*Length of dog spike*	
	mm	*in.*
BG points and crossings	160	6.5
BG track with canted bearing plates; MG points and crossings	135	5.375
MG track with canted bearing plates; NG points and crossings	120	4.75
MG track without bearing plates; NG track with or without bearing plates	110	4.5
BG track without bearing plates	120	4.75

10.2.2 Round Spikes

Round spikes (Fig. 10.5) are used along with anticreep bearing plates for fixing rails to sleepers. These are also used for fixing assemblies of switches onto wooden sleepers. The round spike has a round section of a diameter of 18 mm, and its length depends upon the purpose it serves. Round spikes have become obsolete now.

10.2.3 Fang Bolts

Fang bolts (Fig. 10.5) are employed under the switches for fastening slide chairs to the sleepers. These are used in locations where the gauge is to be preserved.

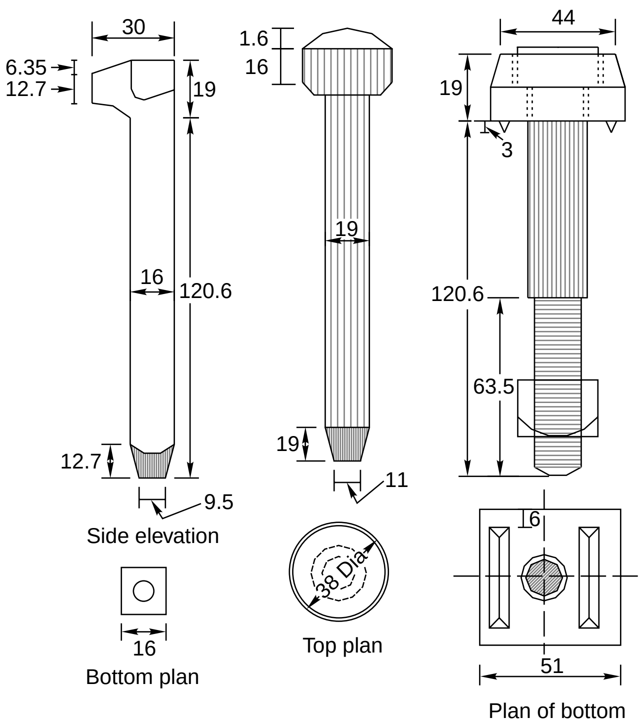


Fig. 10.5 Dog spike, round spike, and fang bolt

10.2.4 Screw Spikes

Indian Railways has developed screw spikes with diameters of 20 mm and 22 mm (Fig. 10.6) to be used on high-speed, main, and trunk routes in order to increase the lifespan of wooden sleepers. Screw spikes with a diameter of 20 mm are called 'plate screws' and are used in place of round spikes for fixing rails to sleepers with the help of anticreep bearing plates while screw spikes with a diameter of 22 mm are called 'rail screws' and are used to directly fasten the rails to the sleepers with or without the use of bearing plates. They are also used on bridges and platform lines. Plate and rail screws should be preferred to round and dog spikes in order to conserve the life of wooden sleepers.

10.2.5 Bearing Plates

Bearing plates are used for fixing wooden sleepers to rails. The different types of bearing plates in use on Indian Railways are described below.

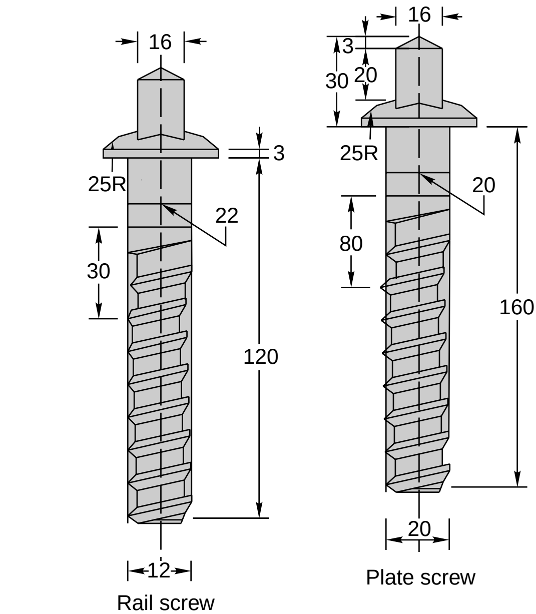


Fig. 10.6 Screw spikes

Mild steel canted bearing plates Mild steel canted bearing plates are used on all joints and curves to provide a better bearing area to the rails. They have a cant of 1 in 20 and a groove in the centre to prevent rocking. Mild steel (MS) canted bearing plates with only round holes are sanctioned for use on the Railways. The normal size of this kind of bearing plate is 260 mm × 220 mm × 18 mm for 52 kg and 90 R rails (Fig. 10.7).

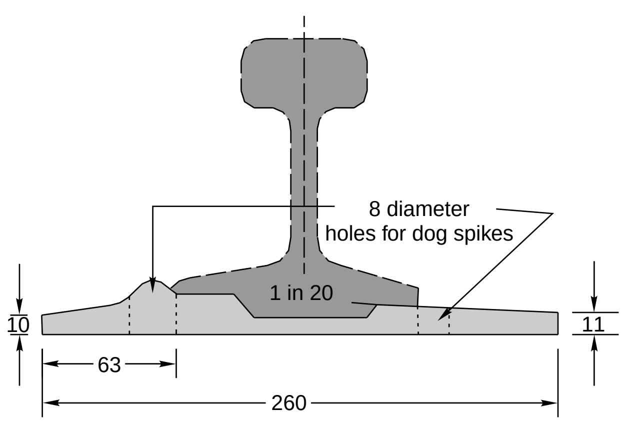


Fig. 10.7 Canted MS bearing plate for 90 R

Flat MS bearing plates Flat MS bearing plates are used at points and crossings in the lead portion of a turnout. No cant is provided in these bearing plates. The size of this bearing plate is 260 mm × 220 mm × 19 mm for 52 kg and 90 R rails (Fig. 10.8).

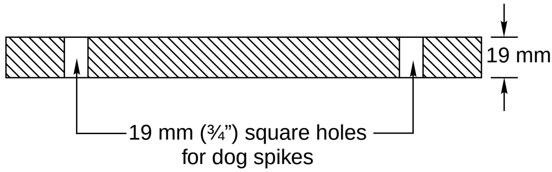


Fig. 10.8 Flat MS bearing plate

Cast iron anticreep bearing plates Cast iron (CI) anticreep bearing plates are provided with wooden sleepers at locations where the rails are likely to develop creep. These bearing plates have a cant of 1 in 20 and can be fixed using normal round spikes. The size of this bearing plate is 285 mm × 205 mm for BG tracks (Fig. 10.9).

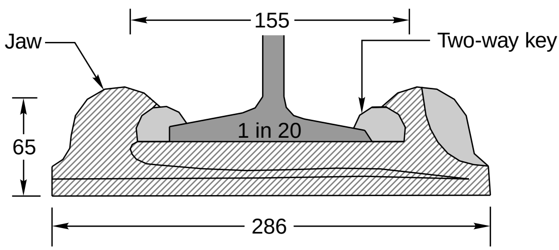


Fig. 10.9 CI anticreep bearing plate

Special CI bearing plates for BH rails Special cast iron bearing plates are used for fixing bull headed (BH) rails. The rail is held in position with the help of a spring key (Fig. 10.10).

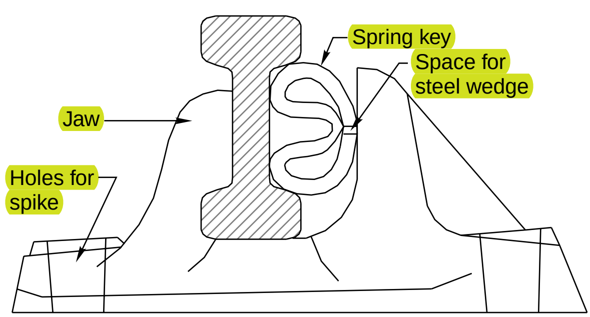


Fig. 10.10 CI bearing plate for BH rail

10.3 Fittings of Steel Trough Sleepers

The fittings required for metal sleepers are different form those used for wooden sleepers. Loose jaws, keys, and rubber pads are used to fix rails to steel sleepers.

Loose jaws

Loose jaws (Fig. 10.11) and keys are used for holding the rail and the steel trough sleeper together. The older type of trough sleepers were easily damaged, cracked, or deformed due to the provision of pressed-up lugs. There problems have been solved by introducing spring steel loose jaws, which have been standardized on Indian Railways. These jaws can be easily replaced whenever necessary. They are manufactured using spring steel and the weight of 100 loose jaws is approximately 28.8 kg.

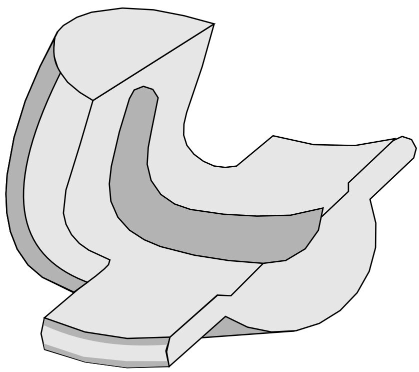


Fig. 10.11 Spring steel loose jaw

Two-way keys

Two-way keys (Fig. 10.12) are universally used for fixing trough sleepers, pot sleepers, and CST-9 sleepers. A two-way taper is provided at both ends of a two-way key and as such the key can be driven in either direction. These keys are manufactured using a special rolled section. The length of the keys for BG is about 190 mm with a taper of 1 in 32. A gauge variation of ±3 mm can be adjusted by altering the extent to which these keys are driven in.

The various methods of driving keys for different types of sleepers are listed in Table 10.5.

Rubber-coated and epoxy-coated fish plates

Some time back, rubber-coated fish plates were used at insulated joints on Indian Railways on a trial basis. The results indicated that these fish plates get damaged early in service, thereby limiting their life. Therefore, epoxy-coated fish plates are now being tried.

10.3.4 Mota Singh Liner

The holes in trough sleepers get elongated during service due to the wear and tear caused on account of moving loads. The Mota Singh liner (Fig. 10.13) is liner used effectively with loose jaws for overcoming the problem of elongated holes.

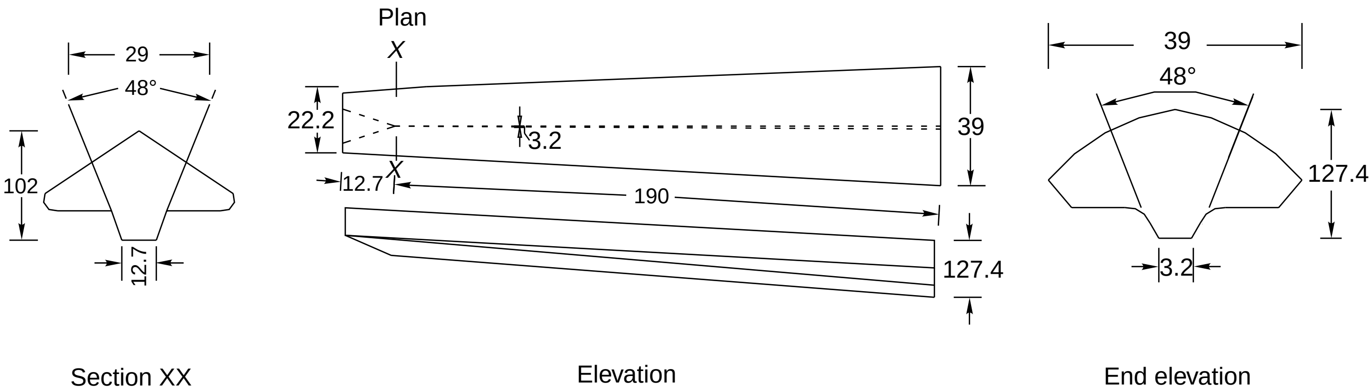


Fig. 10.12 Two-way keys

Table 10.5 Methods of driving keys

Type of sleeper and track	*Direction of driving*
Single line	
CST-9 sleeper (fish-plated, SWR, and LWR tracks)	All the keys in one sleeper should be driven in the same direction. Keys on alternate sleepers should be driven in the reverse direction.
Steel trough sleeper (all types of tracks)	The outer keys on the sleeper should be driven in one direction and the inner keys in alternate sleepers should be driven in the opposite direction.
Wooden sleeper	
▸ Anticreep bearing plates with single-key configuration	All keys should be driven in the same direction. Keys should be driven in reverse direction in alternate sleepers.
▸ Anticreep bearing plates with double-key configuration	The outer keys on a sleeper should be in one direction and the inner keys in the opposite direction. The pattern of driving keys should be reversed in alternate sleepers.
Double line	
CST-sleeper	
▸ Fish-plated and SWR track	The direction of 75% of the keys should be in the direction of the traffic and that of 25% should be in the opposite direction.
▸ LWR track in non-breathing length	75% of the keys should be driven in the direction of traffic and 25% should be driven in the opposite direction.
▸ LWR track in breathing length	All keys should be driven in one direction on one sleeper and in the opposite direction on the next sleeper. The same scheme should be followed up in subsequent sleepers.
ST sleeper	
▸ Fish-plated and SWR track	75% of the sleepers should have all four keys driven in the direction of the traffic and 25% of the sleepers should have the keys driven in the direction opposite to that of the traffic.
▸ LWR track in non-breathing length	75% of the sleepers should have all four keys driven in the direction of traffic and 25% of the sleepers should have all the keys driven in the direction opposite to that of the traffic.
▸ LWR track in breathing length	Two inner keys should be driven in one direction and the other keys in the other direction. Also, the direction of the keys should be reversed in alternate sleepers so as to prevent relative movement between the rail and the sleeper.

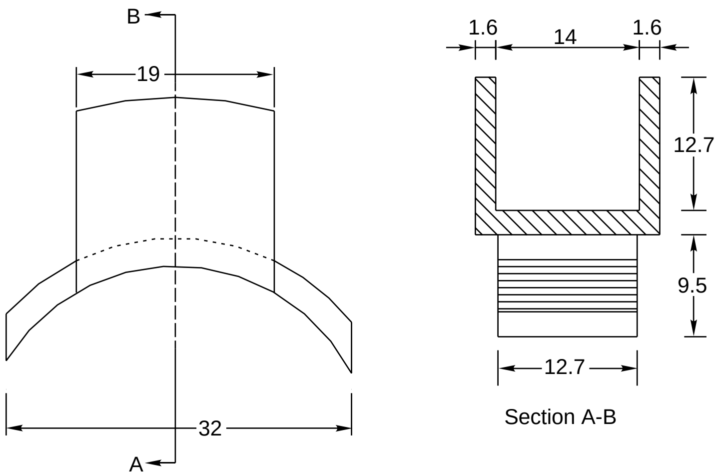


Fig. 10.13 Mota Singh liner (all dimensions are in milimetres)

10.4 Fittings of CI Sleepers

Rails are fixed to cast iron sleepers using cotters and tie bars. These fittings are described below.

Cotters

Cotters (Fig. 10.14) are used for fixing tie bars to CI sleepers. Cotters are classified according to their methods of splitting. The four different types of cotters being used on Indian Railways are as follows.

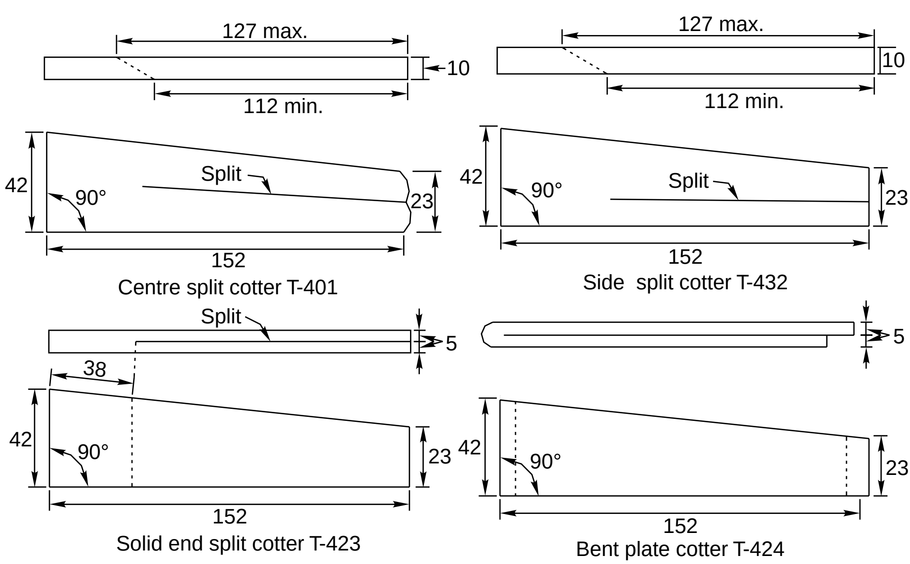


Fig. 10.14 MS cotters (all dimensions are in milimetres)

(a) Centre split cotter
(b) Side split cotter
(c) Solid end split cotter
(d) Bent plate cotter

The overall dimensions, taper, etc. of these four cotters are by and large identical; they only differ in their methods of splitting. The length of a cotter is 152 mm and the approximate weight is 0.80 lb per piece.

MS tie bars

MS tie bars are used for holding the two plates of CST-9 sleepers together. The normal length of a tie bar is 2720 mm for BG and 1870 mm for MG. The section of a BG tie bar measures 50 mm × 13 mm and that of an MG tie bar measures 45 mm × 10 mm.

10.5 Elastic Fastenings

The primary purpose of a fastening is to fix the rail to the sleeper. The rail may be fixed either directly or indirectly with the help of fastenings. In the process, the fastening gets subjected to strong vertical, lateral, and longitudinal forces. The forces, which are predominantly dynamic, increase rapidly with increasing loads and speeds. In addition, vibrations are generated by moving loads mainly on account of geometrical irregularities in the track and due to the forces set up by the imbalance in the rolling stock. The traditional rigid fastening, which so far has fulfilled its task to a certain extent, is no longer able to effectively meet the present challenge of heavy dynamic forces and, therefore, becomes loose under the impact of high-frequency vibrations of the order of 800 to 1000 cycles per second, even at a moderate speed of 100 kmph. In fact, this type of fastening is unable to hold the rail to the sleeper firmly for a satisfactory length of time because of the constant pressure exerted by moving loads. Due to the shocks and vibrations caused by moving loads, the rigid fastenings become loose, an interplay between the components of the track develops, track parameters get affected, and rapid deterioration of the track begins. To solve these problems a fastening which could safeguard track parameters and dampen the vibrations is required. This has led to the development of the elastic fastening.

10.5.1 Requirements of an Elastic Fastening

The ideal elastic fastening should meet the following requirements.

(a) It should hold the gauge firmly in place.
(b) It should have an adequate toe load which should not reduce under service.
(c) It should provide sufficient elasticity to absorb the vibrations and shocks caused by moving loads.
(d) It should help in keeping the track well maintained.
(e) It should offer adequate resistance to lateral forces in order to maintain the stability of the track.

(f) It should provide adequate resistance to the longitudinal forces that are a result of the acceleration of moving loads and other miscellaneous factors. These longitudinal forces tend to cause the development of creep in the track.

(g) It should be of the 'fit and forget' type so that it requires least maintenance.

(h) It should not lose its properties even when it is used over and over.

(i) It should have as few parts as possible and these parts should be easy to manufacture, lay, and maintain.

(j) It should be irremovable so that once fitted it cannot be taken out and as such it should not be vulnerable to sabotage or theft.

(k) It should be universally applicable so that it can be used with wooden, steel, or concrete sleepers.

(l) It should be cheap and long lasting.

10.5.2 Types of Elastic Fastenings

An elastic fastening is usually in the form of a clip. Various types of clips have been developed over the years; these are discussed here in detail.

Pandrol clip or elastic rail clip

The Pandrol PR 401 clip (also known as an elastic rail clip) (Fig. 10.15) is a standard type of elastic fastening used on Indian Railways, earlier manufactured by Messrs Guest, Keens & Williams. It is a 'fit and forget' type of fastening that requires very little attention towards its maintenance. The clip is made of a silico–manganese spring steel bar with a diameter of 20.6 mm and is heat treated. It exerts a toe load of 710 kg for a nominal deflection of 11.4 mm. The toe load is quite adequate to ensure that no relative movement is possible between the rail and the sleeper. Pandrol clips can be driven with the help of an ordinary 4-pound hammer and require no special tools. In order to ensure that the correct toe load is exerted, the Pandrol clip should be driven to such an extent that the outer leg of the clip is flush with the outer face of the CI insert. Figure 10.16 shows an isometric view of the clip fixed on the rail while Fig. 10.17 shows the clip fixed to a rail seat.

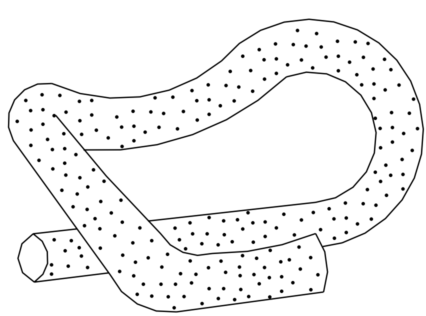


Fig. 10.15 Pandrol clip or elastic rail clip

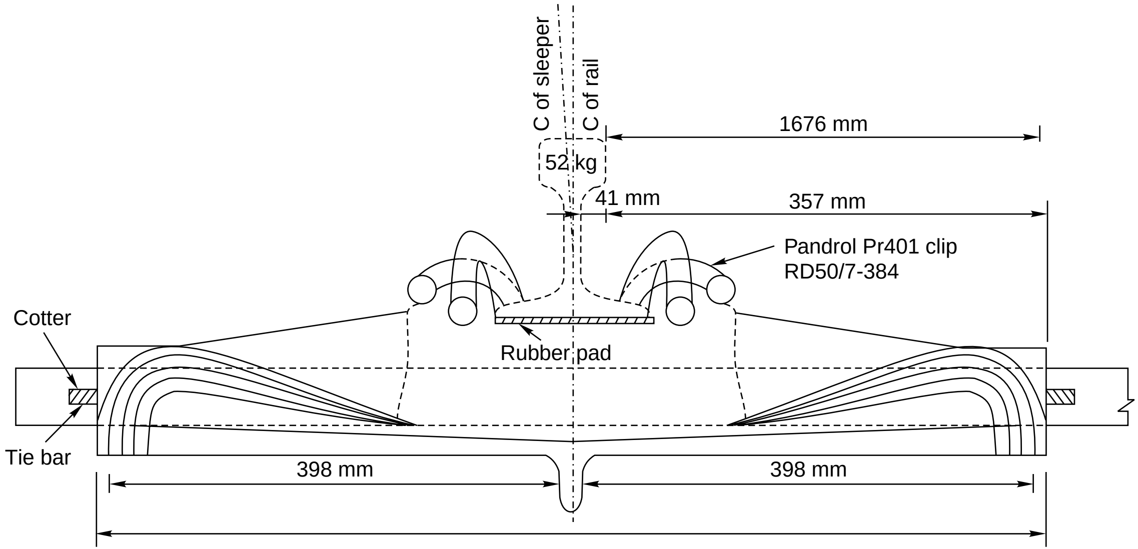


Fig. 10.16 Isometric view of Pandrol clip

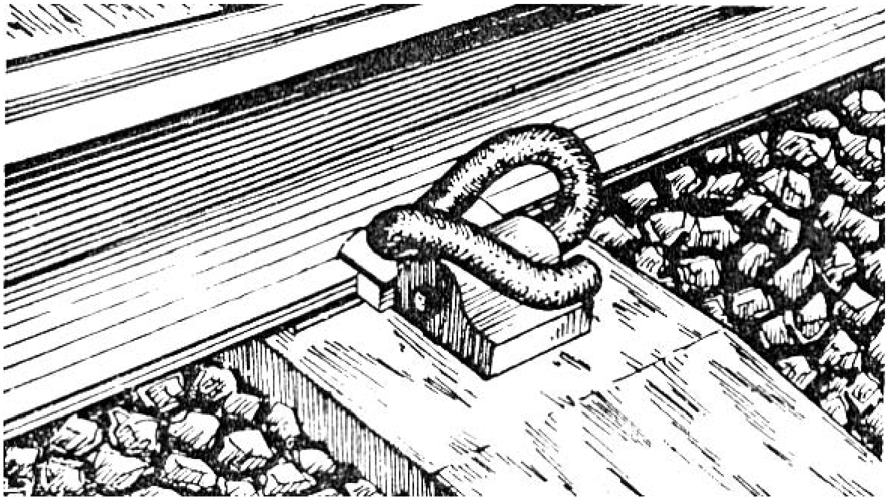


Fig. 10.17 Pandrol clip fixed to the rail seat

The Pandrol or elastic clip can be fixed on wooden, steel, cast iron, and concrete sleepers with the help of a base plate and some other ancillary fittings. Pandrol clips are the most widely used clips with concrete sleepers on Indian Railways. Therefore, it becomes imperative that a detailed account of the same be given.

Concrete sleepers with Pandrol/elastic clips In the case of concrete sleepers, malleable cast iron inserts are punched directly into the sleepers during manufacture. The Pandrol clip is fixed in the holes of the CI insert. A 4.5-mm-thick grooved rubber pad is provided under the rail seat to make it doubly elastic. Insulated liners provide the necessary insulation (Fig. 10.18).

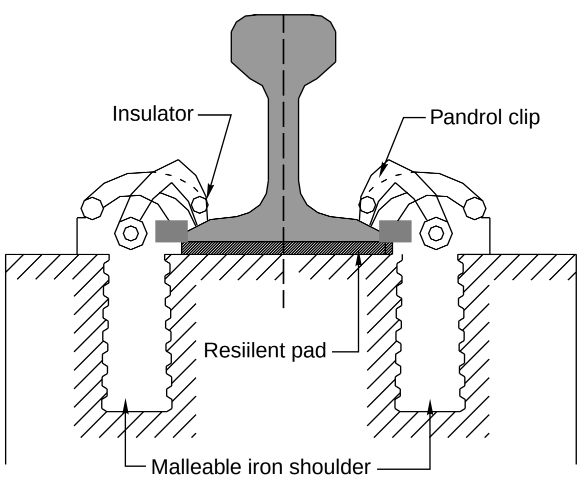


Fig. 10.18 Pandrol clip with concrete sleeper

Drawbacks of Pandrol clip The Pandrol clip suffers from the following drawbacks

1. Their use makes the adjustment of the gauge impossible.
2. The Pandrol clip has a point contact and this causes indentation on the foot of the rail due to a heavy toe load and a small contact area.
3. It does not provide enough safeguard from theft or sabotage because it can easily be taken out using an ordinary hammer.
4. It gets caught inside the malleable cast iron (MCI) insert during service.

Toe load measuring device This device consists of a lever made of silico–manganese steel and is designed to grip the Pandrol rail slip toe. It is used in conjunction with a suitable block which is fitted on the rail head and acts as the fulcrum. To operate the device, a force is gradually applied to the handle and the reading of the dial gauge at which the Pandrol clip toe is just lifted above the rail seat is noted. The reading of the dial gauge indicates the toe load, which is pre-calibrated in the laboratory.

IRN 202 clip

The IRN 202 clip (Fig. 10.19) is an elastic fastening designed by RDSO to suit two-block reinforced cement concrete (RCC) sleepers. The clip is manufactured by the Republic Forge of Hyderabad using a silico–manganese spring steel bar of diameter of 18 mm, suitably heat treated to Brinel hardness number (BHN) 375–415. The assembly is designed for a toe load of 1000 kg and a toe deflection of 18.5 mm. The assembly has a creep resistance generally equal to 50% of the total toe load of the rail.

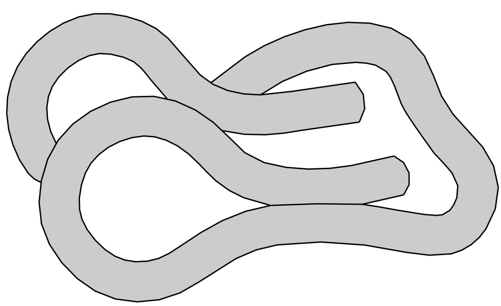


Fig. 10.19 IRN 202 clip

The clip essentially consists of outer legs connected by means of two coils. It is held in position by a bolt and clamp arrangement. The clamp is made up of the same material as the clip. The bolt, which has a diameter of 19 mm, is made of mild steel. The clip holds the track gauge easily and effectively. The inner legs rest against the bottom flange of the rail to provide an elastic gauge check. After the clip is placed in position, the nut is tightened to depress the inner legs with respect to the toe till these touch the sleeper surface. This stage depends on the designed toe load and the toe load deflection. At this stage, it is not possible to tighten the nut any further. The nut will remain in position for quite some time, as the tension in the bolt does not vary much during summer.

The advantage of the IRN 202 clip is that the rail can be changed without removing the fastening simply by loosening the bolt and pushing the rail out. However, the IRN 202 clip suffers from the following drawbacks.

1. The corrosion of the highly stressed part (heel) of the assembly can lead to the development cracks.
2. It is not a fit and forget type of fastening and requires frequent attention such as oiling and tightening of the nuts to maintain the required toe load.
3. It is a comparatively costlier and heavier clip.

Lock spikes

Lock spikes (Fig. 10.20) are manufactured by Messrs Lock Spike Ltd, London for use with wooden sleepers. The lock spike type LG-20 has been tried on Indian Railways. It is a 165-mm- (6.5-in.) long spike with a round section of diameter 16 mm (5/8″). The sizes of the holes bored into the sleeper are 14 mm and 12 mm for hard wood, and soft wood respectively. The spike, which appears to have a good future, is still under trial.

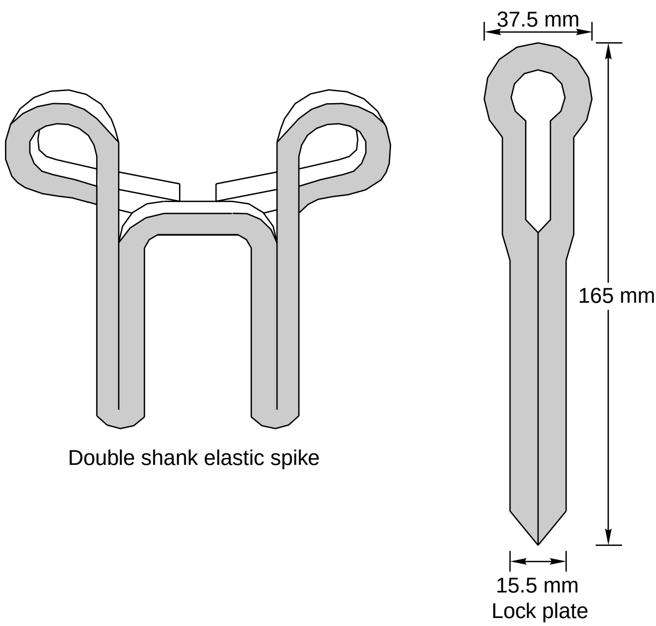


Fig. 10.20 Lock spike

Spring steel clip

A large number of spring steel clips (Fig. 10.21), supplied mostly by Messrs Guest, Keens & Williams, have been tried on Indian Railways. The assembly consists of a double elastic fastening used on a prestressed concrete sleeper. In this assembly, the rail rests on a grooved rubber pad and is held vertically by a pair of spring clips at each rail seat. The clip is pressed with the help of a nut tightened on a 22-mm bolt, which is inserted from the underside of the sleeper. The clip is manufactured using EN-48 steel. The nut is tightened to a torque of 100 ft lb to obtain a resistance of 1 t per pair of clips. The clip is still in its experimental stage on Indian Railways.

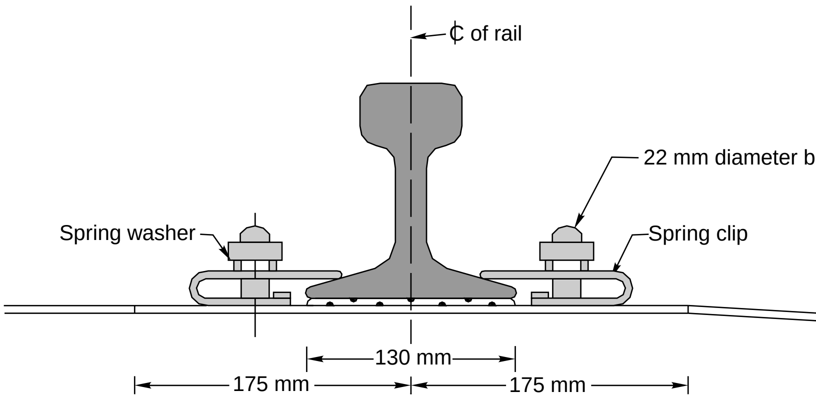


Fig. 10.21 Spring steel clip

Elastic rail clip MK-III

The RDSO has designed a new type of elastic rail clip known as ERC MK-III (Fig. 10.22) which suits both 52-kg and 60-kg rails along with 6-mm-thick rubber pads. In the case of 60-kg rails, two liners of 16 mm thickness are used, whereas in the case of 52-kg rails, one liner of 16 mm thickness is used on the non-gauge side and another liner of 10 mm thickness is used on the gauge side. The clip can also be used with 6-mm-thick rubber pads in place of the usual 4.5-mm-thick rubber pads on the existing 52-kg PRC sleeper.

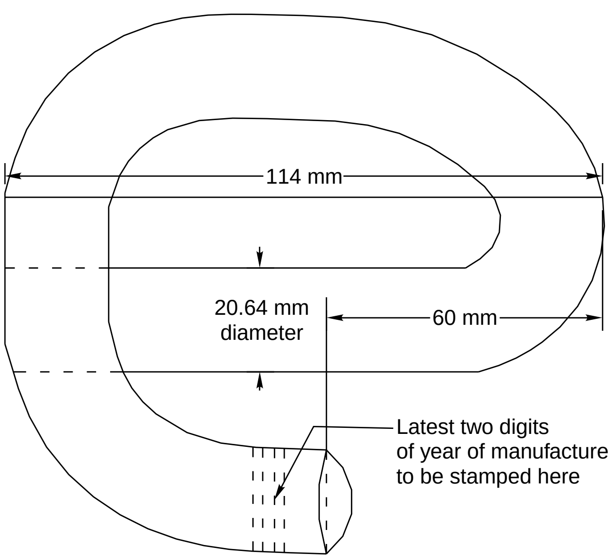


Fig. 10.22 Pandrol clip (ERC rail clip) MK III

The ERC MK-III clip has been modified from the standard elastic rail clip to the extent that the distance of the toe of the clip has increased with respect to the centre leg. The space curves of the clip have also been modified to achieve a higher toe load. The diameter of the standard ERC has been retained, i.e., 20.6 mm.

The new ERC MK-III has a toe load of 900–1100 kg with a toe deflection of 15.5 mm. The clip is still under trial.

Limitations of elastic rail clip The elastic clip (or Pandrol clip) presently being used on Indian Railways has the following limitations.

1. The elastic rail clip (ERC) does not permit 52-kg rails to be interchangd with 60-kg rails. Therefore, whenever traffic requirements demand the replacement of 52-kg rails with 60-kg rails, the sleepers also have to be replaced or costlier special steel alloy rails have to be used.
2. The ERC can be easily removed from the track.
3. The ERC gets jammed/rusted in the insert and tends to lose the designed toe load.

The only fastenings in the world proven to permit the interchangeability of 52-kg rails with 60-kg rails are the HM fastenings of German design and the NABLA fastenings of French design. The RDSO has recently designed an elastic rail clip (mark III) which also permits interchangeability of the two types of rails, but it is still in its trial stage.

Herbert Meir fastening

The Herbert Meir (HM) fastening (Fig. 10.23) basically consists of four coach screws which are tightened against the plastic dowels of the PRC sleepers and press the HM clip assembly to give the desired toe load. Each clip weighs about 510 g and can give a toe load of about 1 t. The gauge is maintained with the help of an angled guide plate. A thin insulated shim is placed between the angled plate and the concrete sleepers. A grooved rubber pad is placed below the seat to provide the necessary dampening effect and resistance to the lateral movement of rails.

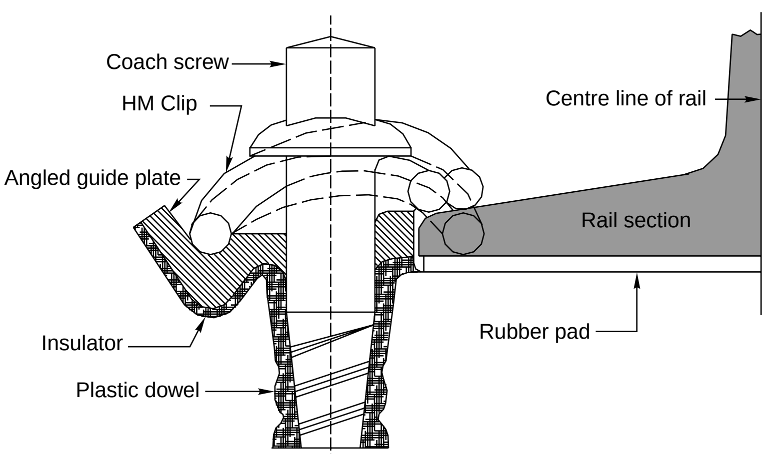


Fig. 10.23 HM fastening

The HM fastening can be used for 52-kg as well as 60-kg rails by using a suitable size of angled guide plates and insulating shims.

10.6 Other Fittings and Fastenings

This section discusses malleable cast iron inserts, rubber pads, composite liners, and pilfer-proof elastic fastenings.

10.6.1 MCI Inserts

Malleable cast iron inserts are directly fixed onto concrete sleepers during manufacture. MCI inserts are manufactured according to the Indian Railway Standard (IRS) specification T-32-76. These inserts are of two types.

(a) Stem-type MCI insert for use in normal pre-tension concrete sleepers. This insert is provided in concrete sleepers being manufactured in all the concrete sleeper factories in India except the one located at Allahabad. The weight of the stem-type insert is about 1.6 kg per piece.

(b) Gate-type MCI insert for use in the post-tension concrete sleepers being manufactured at Allahabad. The approximate weight of the gate-type MCI insert is 1.7 kg per piece.

10.6.2 Rubber Pads

A rubber pad (Fig. 10.24) is an integral part of an elastic fastening. It is provided between the rails and the sleepers and has the following functions.

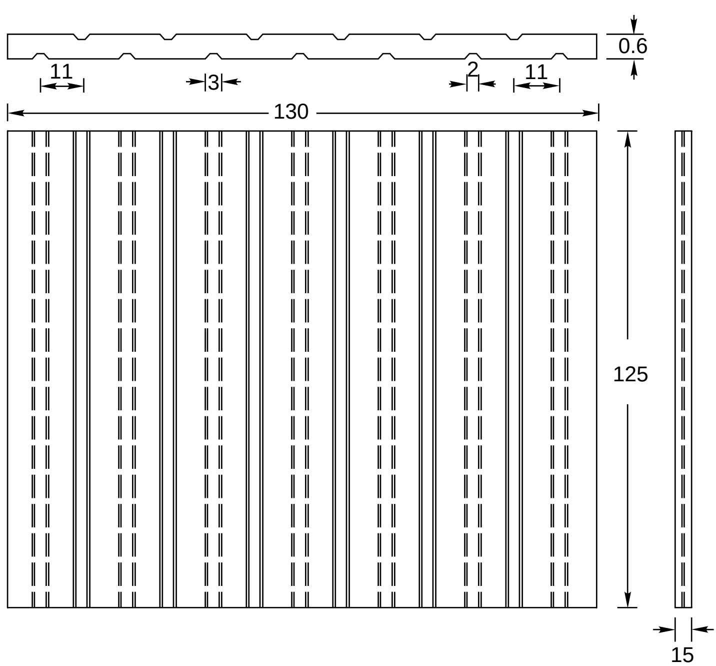


Fig. 10.24 Rubber pad

(a) It absorbs shocks.
(b) It dampens and absorbs vibrations.
(c) It resists the lateral movements of the rails.
(d) It prevents the abrasion of the bottom surface of the rail, which would otherwise come in direct contact with the sleepers.
(e) It provides electrical insulation between the rails in an electrified area.

Indian Railways uses grooved rubber pads of 4.5 mm thickness made of special quality rubber. The grooves aid in the uniform distribution of the load on sleepers and help to limit the lateral expansion of the rubber under the pressure of dynamic loads.

The RDSO has recently designed 6-mm-thick grooved rubber pads with horns (Drg. No. RDSO/T-37) for use on 60-kg rails (Fig. 10.25). It was noticed that normal 4.5-mm-thick rubber pads (IRST-37-1982) got crushed wihtin 6–7 years and, therefore, thicker, grooved rubber pads with a service life of 15–20 years were designed particularly for use on 60-kg UIC rails. These rubber pads are still under trial.

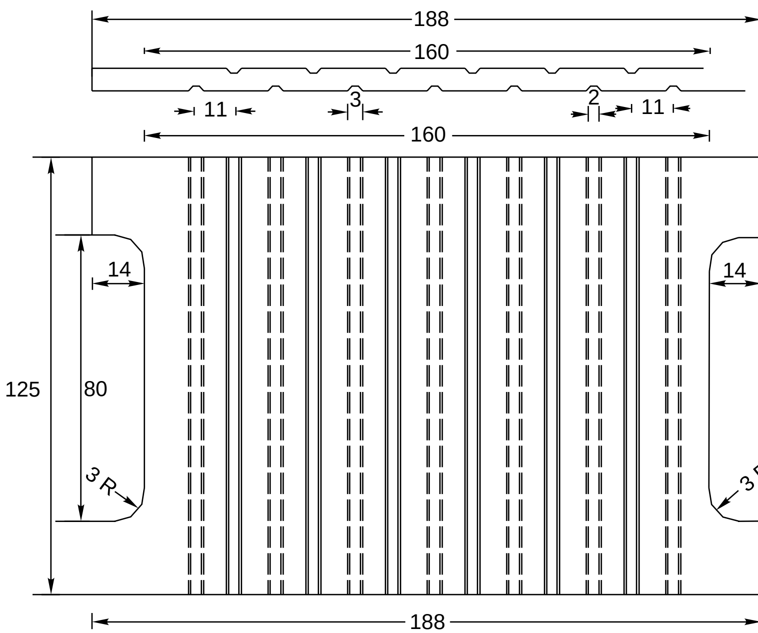


Fig. 10.25 6-mm-thick grooved rubber pad

10.6.3 Composite Liners

The Indian Railways mostly uses nylon insulating liners. These liners, however, get crushed under the toe load exerted by Pandrol clips. To eliminate such premature failure, the following two types of composite liners have been evolved by RDSO.

(a) Composite liner with malleable cast iron and nylon components (Drg. No. RDSO/T653/1)

(b) Composite liners with MS and nylon components (Drg. No. RDSO/T-1895)

These liners have been developed on the basis of the designs of the liners adopted on British Railways, which have been reported to provide trouble-free service. Composite liners have been used on Indian Railways for the last few years and are serving the railways well.

Glass-filled nylon liners

The RDSO has developed glass-filled nylon liners (Fig. 10.26) (GFN-66) of 4 mm thickness particularly for track-circuited areas and sections subject to server corrosion. These glass-filled nylon liners are considered to be technically superior to other liners because they are single piece, have a longer life, and are free from corrosion. These liners are used extensively on Indian Railways particularly with the ERC clip assembly on 60-kg and 52-kg rails and PRC sleepers.

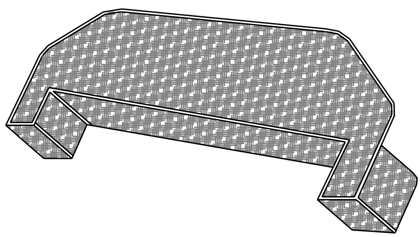


Fig. 10.26 Glass-filled nylon liner

It has been noticed that the GFN-66 liners tend to break, particularly in yards where these liners have been fitted in the ERC clip assembly on concrete sleepers. This happens due to the rusting of the rail surface and uneven seating. To avoid breakage of GFN-66 liners, it is necessary that proper precautions be taken during initial laying to ensure that the rail surface is free from rust, etc. and that the liners are fitted evenly on the 1 in 6 sloping surface of the rail flange.

A new design of GFN-66 liners with a thickness of 6 mm (Drg. No. DSO/T-2505 Alt II) has recently been developed and is expected to be sturdier and provide a better service life.

10.6.4 Pilfer-proof Elastic Fastenings for Concrete Sleepers

The present design of elastic fastenings (Pandrol clips) is such that they can be easily removed by a single stroke of a hammer. A new type of elastic rail clip, which is pilfer-proof, has been recently developed by RDSO. A pilfer-proof elastic fastening may be defined as an elastic fastening system which is easy to fit in the assembly but is difficult to remove without damaging the system.

The design of a pilfer-proof elastic rail fastening consists of clip of almost the same design as that of the normal elastic fastening as well as a new fitting known as the *pilfer-proof circlip*. The circlip is a standard mechanical component manufactured according to IS specifications and is generally used for restraining the axial movements of the components mounted on shafts.

10.7 Testing of Fastenings

Both elastic and rigid fastenings are tested in the laboratory for their suitability in the field. The vibrogir and pulsator are used to test these fastenings.

The vibrogir is used in laboratories for checking the effectiveness of various fastenings. With the help of this equipment it is possible to produce high-frequency vibrations in the laboratory, very similar to those produced on a real track. By applying a frequency of 50 Hz, the rail and sleeper are made to vibrate at a rate of 700–800 Hz with an acceleration of 70 g and an amplitude of the order of 0.1–0.3 mm. One hour of working of a vibrogir corresponds to almost 4.05 GMT of traffic and 300 hours of its working creates the same effect on a fastening as 20 years of service under normal track conditions.

The pulsator not only simulates vibrations just like the vibrogir, but also applies vertical and lateral pressure on the rail fastening at a frequency of 250–500 cycles/minute.

Tests carried out with the help of vibrogirs and pulsators clearly establish the superiority of elastic fastenings over rigid fastenings.

Summary

Fittings hold rails in position and thus help provide a smooth ride. Fish plates and bolts are used to join the rails in series while different types of fastenings are used to fix the rails to the sleepers. The traditional rigid types of fastenings are not able to meet the challenges posed by heavy dynamic forces and become loose under high-frequency vibrations. Elastic fastenings are found to be very suitable for high-speed tracks. New design of elastic fastenings are being developed to overcome as many drawbacks as possible.

Review Questions

1. With the help of a suitable sketch explain the assembly of the Pandrol clip in elastic fastenings for concrete sleepers.
2. Illustrate with sketches the various fastenings used to fasten rails to sleepers. Discuss their merits and demerits.
3. Explain briefly the functions of the following in a railway track.
   (a) Hook bolt
   (b) Fish plate
   (c) Tie bar
   (d) Cotters
   (e) Screw spike
4. What do you understand by anchors and what are their functions in railways? What are the advantages and disadvantages of bearing plates?
5. Name the different types of track fittings. Name the different types of spikes generally used and draw a sketch of any one of them.
6. Draw the details of a rail held to a wooden sleeper by the following.
   (a) Dog spikes on an MS bearing plate

   (b) Anticreep keys on a CI bearing plate
   (c) Pandrol clip on a CI bearing plate

   What are the advantages and disadvantages of these fastenings?

7. What is the difference between an ordinary fish plate and a combination fish plate?
8. What are the requirements of an elastic fastening? Briefly describe the various elastic fastenings being used on Indian Railways.
9. Describe the various type of fittings used for wooden sleepers and steel trough sleepers.
10. What are the requirements of an elastic fastening? Draw a sketch of an elastic rail clip and explain how it is fixed to a concrete sleeper.
11. Describe the functions of a rubber pad. Draw a dimensioned sketch of the same.
12. Differentiate between the following.
    (a) Fat bearing plate and canted bearing plate
    (b) Dog spike and screw spike
    (c) Ordinary fish plate and combination fish plate
    (d) Cotters and liners
    (e) Elastic rail clip and spring steel clip
    (f) Glass-filled nylon liners and Mota Singh liners
13. Write short notes on the following.
    (a) Loose jaw
    (b) HM fastening
    (c) Pilfer-proof elastic fastening
    (d) Vibrogir and pulsator

Week-(16)

MD Ehasan Kabir

CHAPTER
7

Sleepers

Introduction

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. The characteristics of these sleepers and their suitability with respect to load conditions are described in this chapter.

7.1 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.

(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.

7.2 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. The standard spacing specifications adopted for a fish-plated track on Indian Railways are given in Table 7.1. The notations used in this table are explained in Fig. 7.1.

Table 7.1 Spacing of sleepers for a fish-plated track

Spacing of sleepers	*Broad gauge centre-to-centre spacing (mm)*		*Meter gauge centre-to-centre spacing (mm)*	
	Wooden	*Metal*	*Wooden*	*Metal*
Between joint sleepers (*a*)	300	380	250	330
Between joint sleepers and the first shoulder sleeper (*b*)	610	610	580	580
Between first shoulder sleeper and second shoulder sleeper (*c*) for sleeper density $M + 4$	700 (640)*	720 (630)	700 (620)	710 (600)
Between intermediate sleepers (*d*) for sleeper density $M + 4$	840 (680)	830 (680)	820 (720)	810 (640)

* Values within parentheses are those for sleeper density $M + 7$.

Now-a-days sleeper density is also indicated in terms of the number of sleepers/km. The sleeper spacing required for various sleeper densities is given in Table 7.2.

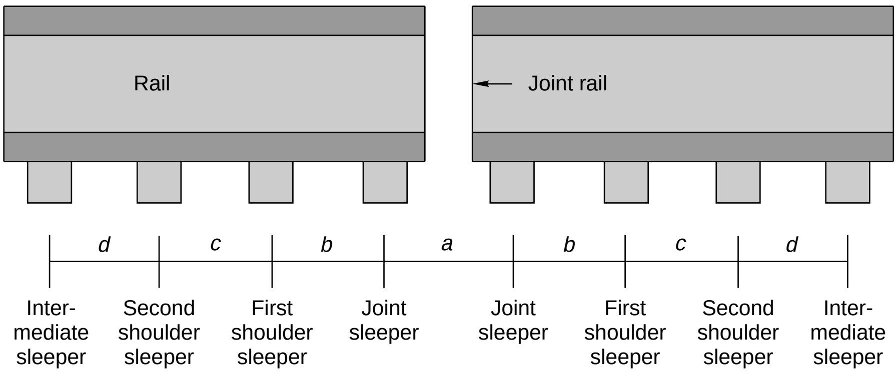


Fig. 7.1 Spacing of sleepers on a fish-plated track

Table 7.2 Spacing of sleepers for welded track

No. of sleepers per km	*Exact centre-to-centre spacing required as per calculation (mm)*	*Centre-to-centre spacing to be provided in the field (mm)*	
		LWR track	*SWR track*
1660	602.4	600	–
1540	649.3	650	660
1310	763.3	–	780

7.3 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. Table 7.3 compares the important characteristics of these types.

Table 7.3 Comparison of different types of sleepers

Characteristics	*Type of sleeper*			
	Wooden	*Steel*	*CI*	*Concrete*
Service life (years)	12–15	40–50	40–50	50–60
Weight of sleeper for BG (kg)	83	79	87	267
Handling	Manual handling; no damage to sleeper while handling	Manual handling; no damage to sleeper while handling	Manual handling; liable to break by rough handling	No manual handling; gets damaged by rough handling

(*contd*)

Table 7.3 (*contd*)

Characteristics	*Type of sleeper*			
	Wooden	*Steel*	*CI*	*Concrete*
Type of maintenance	Manual or mechanized	Manual or mechanized	Manual	Mechanized only
Cost of maintenance	High	Medium	Medium	Low
Gauge adjustment	Difficult	Easy	Easy	No gauge adjustment possible
Track circuiting	Best	Difficult; insulating pads are necessary	Difficult; insulating pads are necessary	Easy
Damage by white ants and corrosion	Can be damaged by white ants	No damage by white ants but corrosion is possible	Can be damaged by corrosion	No damage by white ants or corrosion
Suitability for fastening	Suitable for CF* and EF†	Suitable for CF and EF	Suitable for CF only	Suitable for EF only
Track elasticity	Good	Good	Good	Best
Creep	Excessive	Less	Less	Minimum
Scrap value	Low	Higher than wooden	High	None

* CF stands for conventional fastening.
† EF stands for elastic fastening.

7.4 Wooden Sleepers

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

Specifications The size of a wooden sleeper should be economical. It should provide the desired strength to the sleeper as a beam as well as adequate bearing area. The depth of a sleeper governs its stiffness as a beam and its length and width control the necessary bearing area. The bearing length under each rail seat is 92 cm (3 ft) for a BG wooden sleeper, thereby giving an area of 2325 cm^2 under each rail seat. The sizes of sleepers used for BG, MG, and NG as well as the bearing area per sleeper are given in Table 7.4.

Table 7.4 Sizes of wooden sleepers and bearing areas

Gauge	*Size (cm)*	*Bearing area per sleeper (m^2)*
BG	275 × 25 × 13	0.465
MG	180 × 20 × 11.5	0.3098
NG	150 × 18 × 11.5	0.209

Wooden sleepers required for bridges, points, and crossings are of a thicker section—25 cm × 15 cm or 25 cm × 18 cm.

Composite sleeper index The composite sleeper index (CSI), which evolved from a combination of the properties of strength and hardness, is an index used to determine the suitability of a particular timber for use as a sleeper from the point of view of mechanical strength.

The CSI is given by the formula

$$\text{CSI} = \frac{S + 10H}{20} \tag{7.1}$$

where S is the figure for the general strength for both green and dry timber at 12% moisture content and H is the figure for the general hardness for both green and dry timber at 12% moisture content. The minimum CSI prescribed on Indian Railways are the following.

Type of sleeper	*Minimum CSI*
Track sleeper	783
Crossing sleeper	1352
Bridge sleeper	1455

Bearing plates are invariably used on sleepers with a CSI value of 82 or less. The CSI values for some of the timber species recommended by Indian Railways for making sleepers are as follows.

Sal	112
Teak	82
Deodar	63
Chir	54

Wooden sleepers have the following main advantages and disadvantages.

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

At present wooden sleepers are being procured from the State Forest Departments. A detailed inspection of sleepers is done at the time of procurement to ensure that the sleepers accepted are of good quality and free from defects. The main defects normally found in sleepers are

(a) Centre heart
(b) Presence of knots, warps, wanes, and shakes
(c) Split ends
(d) Twisted or cross grains

The normal service life of wooden sleepers in India is only about 15 years as against a much longer service life obtained on other advanced railways. The weather conditions, particularly the rains, humidity, etc., are responsible for the shorter life-span of these sleepers in India. A committee was appointed by the Railway Board in the year 1972 to examine the measures for increasing service life and improving the utilization of wooden sleepers. The main recommendations of this committee are as follows.

(a) Sleepers should be procured in nominated sleeper depots of the Railways. The inspection of sleepers should also be done by the Railways in addition to the Forest Department.
(b) The net retention of creosote and fuel oil (in the ratio of 1:1) for the sleeper should be a minimum of 8 lb/ft^3.
(c) Bearing plates and elastic fastenings as well as modern methods of maintenance such as measured shovel packing (MSP) and mechanical tamping should be progressively used with wooden sleepers to avoid damage to the sleepers and ensure a longer life for them. Bearing plates should be compulsorily used when traffic density exceeds 20 GMT on BG routes and 5 GMT on MG routes as well as on joint sleepers and on curves of radius 1,500 metre and sharper curves.
(d) Spike-killed sleepers should be systematically reconditioned.
(e) Track depots should be organized in each railway to undertake the operations of end-binding, adzing, and pre-boring of sleepers.

7.4.1 Durable and Non-durable Types of Sleepers

Wooden sleepers may be classified into two categories, durable and non-durable.

Durable type

Durable sleepers do not require any treatment and can be laid directly on the track. The Indian Railway Board has classified particular categories of sleepers as the durable type. These are sleepers produced from timbers such as teak, sal, nahor, rosewood, anjan, kongu, crumbogam kong, vengai, padauk, lakooch, wonta, milla, and crul.

Non-durable type

Non-durable sleepers require treatment before being put on the track. Non-durable sleepers are made of wood of trees such as chir, deodar, kail, gunjan, and jamun.

If a non-durable type of sleeper is put onto the track directly without any preservative treatment, the sleeper will decay in a very short time. If, however, such sleepers are treated before use, they last longer and their life is comparable to that of durable sleepers. Fir sleepers, however, have not provided good service and their use has been restricted to only those trunk routes and main lines where traffic density is not more than 10 GMT [gross million tonne(s) per km/annum]. The primary service life of a wooden sleeper is approximately as follows:

	BG	MG
Durable	19 years	31 years
Non-durable	12.5 years	15.5 years

7.4.2 Treated and Untreated Sleepers

Wooden sleepers are also sometimes classified as hard wood and soft wood sleepers depending upon the origin or species of the wood of which these are made. Broadly speaking, timber produced from trees with broad leaves is known as *hard wood* and that obtained from trees bearing long leaves is considered *soft wood*. Some of the hard wood varieties also require treatment before being used in the track. As per the recommendations of the committee, the use of the terms 'durable' and 'non-durable' as well as 'hard' and 'soft' should be done away with to avoid confusion. The committee recommended that for simplification and rationalization, wooden sleepers should be classified in two categories:

(a) 'U' or *Untreated sleepers* comprising of all the sleepers made of wood from naturally durable species.
(b) 'T' or *Treated sleepers* consisting of the rest of the sleepers.

Treatment of sleepers

Indian Railways has set up four sleeper treatment plants at the locations given below for treating non-durable sleepers:

Dhilwan (Punjab) in Northern Railways	1923
Naharkatia (Assam) in North Frontier	1928
Clutterbuckganj (UP) in North East	1955
Olvakot (Kerala) in Southern Railways	1957

All these plants utilize the pressure treatment process and the preservative is forced into the wood under pressure using any one of the following three methods.

Full cell (Bethell) process In the Bethell process, a cylinder loaded with the charge for about 300–400 sleepers is first subjected to a vacuum of 55–60 cm of mercury for 20–30 minutes by means of a vacuum pump. Hot creosote oil is then forced into the cylinder at a pressure of 150–180 psi at a temperature of 180°F. This pressure is maintained for a period of 50–70 minutes till the desired amount of absorption is obtained. Thereafter, the pressure is reduced and the cylinder is drained off the creosote oil. A final vacuum of 55 cm of mercury is applied to free the timber of excess preservative. The whole process takes about 2–3 hours. This process is normally used when maximum retention of creosote oil is required for a particular type of sleeper such as that made of kail, deodar, fir, etc. At present this method is in use in Olvakot, Clutterbuckganj, and Dhilwan plants for various types of wood.

Empty cell (Rueping) process In the Rueping process, wooden sleepers loaded into the cylinder are first subjected to an initial air pressure of 3.5 to 5.25 kg/cm^2 for about 20–30 minutes. Afterwards, without reducing the pressure, hot creosote oil is forced into the cylinder at a temperature of 180°C to 210°C. The pressure is then raised to a value of 10.5–19.6 kg/cm^2 and maintained for a period of 20–30 minutes till the desired absorption is achieved. Finally, the pressure is released, the cylinder is drained off the creosote, and a final vacuum of 55 cm of mercury is created to drain off the excess preservative. The whole process of treatment takes about 2–3 hours per charge. This process is generally employed for treating porous timbers and is used in Dhilwan and Clutterbuckganj depots for chir sleepers. In this process, air in the cell is entrapped, thereby limiting the preservative to be absorbed by the sleeper to a certain extent.

Empty cell (Lowry) process In the Lowry process, the cylinder loaded with timber charge is filled and then subjected to a pressure of 180 lb, which is sufficient to ensure proper impregnation. The cylinder is then drained off and the timber subjected to a final vacuum of 55 cm of mercury for a period of 45 minutes or so. The air entrapped in the timber cells forces the excess preservative out. Preservative recovery is greater in this case than in the full cell process but is less than in the Rueping process. This process is used in the Naharkatia plant for very green species of timber.

Prophylactic treatment of sleepers Prophylactic treatment is given to the sleepers by using patent chemicals such as arsenic pentaoxide, copper sulphate, and potassium dichromate solution in water 1:3:4 wt (60%) to prevent infection at the forest head and in the treatment plant. This is necessary an as appreciable amount of time elapses in transferring the sleepers from the forest depots to the treatment plant.

Seasoning of sleepers

Wooden sleepers are seasoned to reduce the moisture content so that their treatment is effective. The Indian Standard code of practice for preservation of timber lays down that the moisture content in the case of sleepers to be treated by pressure treatment should not be more than 25%.

The seasoning of sleepers can be done by any one of the following processes.

Artificial seasoning in kiln This is a controlled method of seasoning the timber, normally used in the USA and other advanced countries, under conditions of temperature and relative humidity, which are in the range of natural air seasoning.

Boulton or boiling under vacuum process This is a process in which unseasoned wood is treated with hot preservative to remove the moisture content. This is adopted in the Naharkatia depot.

Air seasoning This is the method adopted extensively for the seasoning of wooden sleepers in India. The sleepers are stacked in the timber yard and a provision is made for enough space for the circulation of air in between the sleepers. The sleepers are stacked in any one of the following ways:

(a) One and nine method (Fig. 7.2)
(b) Close crib method
(c) Open crib method (Fig. 7.3)

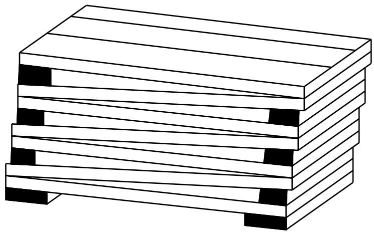


Fig.7.2 One and nine method

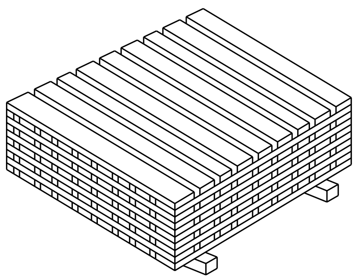


Fig. 7.3 Open crib method

Normally, the one and nine method is adopted on Indian Railways for stacking the sleepers. About 6 months are required to air season the timber fully by this method.

7.4.3 Laying of Wooden Sleepers

Great care should be taken in laying wooden sleepers. Untreated wooden sleepers should be laid with the sapwood side upwards and the heartwood side downwards so as to ensure minimum decay due to fungus, etc., attacking from below. More moisture would also percolate into the sleepers if laid otherwise. In the case of treated sleepers, however, the heartwood side is kept upwards and the sapwood side downwards. This is done because the sapwood side contains more creosote and is liable to less damage from vermin and fungus.

7.4.4 Adzing of Wooden Sleepers

In order to enable the rails to be slightly tilted inwards at a cant of 1 in 20, wooden sleepers are required to be cut to this slope at the rail seat before laying. This process of cutting the wooden sleeper at a slope of 1 in 20 is known as 'adzing of the wooden sleeper'.

It may be pointed out that adzing or cutting of a wooden sleeper at a slope of 1 in 20 is done with great care, otherwise the slope will vary from sleeper to sleeper resulting in a rough ride. The adzed surface of a wooden sleeper is treated with coal tar or creosote to ensure proper protection of the surface. Normally, adzing of a wooden sleeper is done only when bearing plates are not provided.

7.5 Steel Channel Sleepers

In view of the great shortage of wooden sleepers, steel channel sleepers have been developed by Indian Railways particularly for use on girder bridges. Steel channel sleepers can be used for welded plates, riveted plates, as well as open web girders.

Composite sleepers have been developed indigenously in India as a replacement for wooden sleepers. These are made from waste products such as used rubber tyres, and the manufacturers claim a lifespan of about 40 years for these sleepers. The Patel Group of Industries is one such firm that has developed these composite sleepers.

Composite sleepers are similar to wooden sleepers and use similar fittings. These sleepers are under trial and the results so far have been quite encouraging.

7.6 Steel Trough Sleeper

About 27% of the track on Indian Railways is laid on steel sleepers (Fig. 7.4). 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.

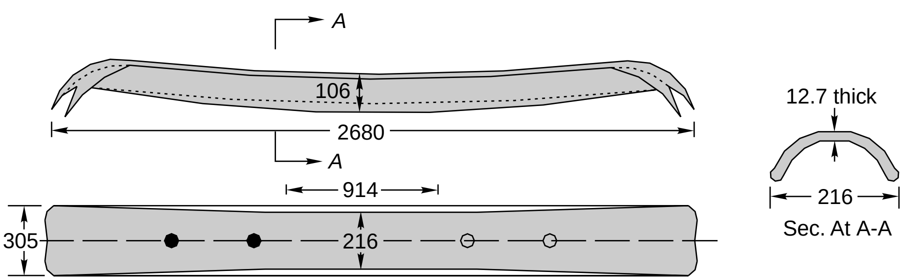


Fig. 7.4 Steel trough sleeper (BG 90 R)

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

(c) Liable to become centre-bound because of slopes at the two ends
(d) Develops cracks on rail seats during service
(e) Design is rail specific

7.6.1 Design Features

The steel trough sleeper essentially consists of a rolled steel plate of about 2 mm thickness pressed into a suitable trough shape and the rail seat canted to 1 in 20. The ends of the rolled section are flattened out in the shape of a spade to retain the ballast. Two alternative types of sleepers have been designed for each rail section as per the following details.

1. In one type, the lugs or jaws are pressed out of the plate itself to accommodate the foot of the rail and the key (Fig. 7.5). There are several maintenance problems with these pressed up lugs, as they give way due to the movement of the keys as well as due to the vibrations and impact of the moving loads.
2. In order to obviate this defect, another sleeper design has been adopted. In this design, two holes are punched into either side of the plate to accommodate specially designed 'loose jaws' (Fig. 7.6). The rails are held with the help of two standard keys driven either into the pressed up lugs or into the loose jaws.

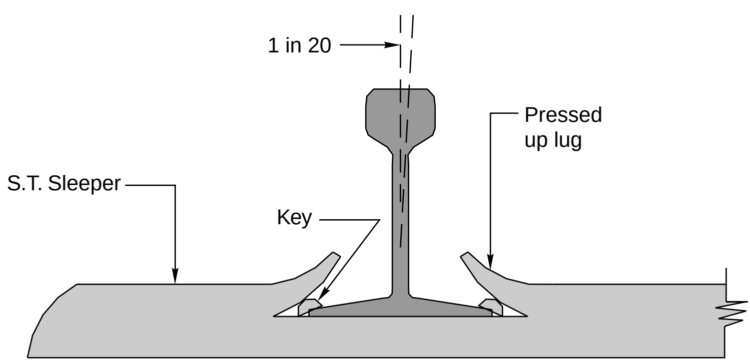


Fig. 7.5 ST sleeper with pressed up lugs

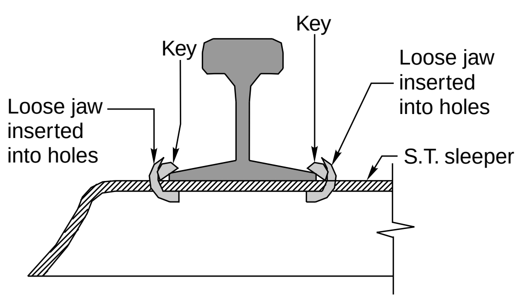


Fig. 7.6 Sleeper with losse jaws inserted into holes

The adjustment of the gauge to the extent of ± 3 mm is done by properly driving in the keys. In the double-line section, the keys are driven in the direction of the traffic. The approximate weight of a standard BG trough sleeper is 81 kg and that of an MG sleeper is 35 kg. The steel trough (ST) sleeper has an average life of about 50 years. It is an acceptable type of sleeper for use with long welded rails because of its lateral stability and its adaptability for use along with elastic fastenings.

7.6.2 Classification

All steel sleepers conforming to Indian Railways specifications T-9 are classified as first quality sleepers. The sleepers not accepted as first quality but free from the following defects are termed second quality steel trough sleepers.

(a) Inward tilt at rail seat beyond the limits of 1 in 15 to 1 in 25
(b) Sleepers with a twist
(c) Heavy scale fitting or deep grooves or cuts
(d) Deep guide marks at heads, blisters, etc.

All first quality sleepers are normally marked by a green dot. Sleepers that have been rejected as first quality sleepers on account of pipes, seams, and laps but are free from the defects indicated above are marked with a cross (×) in yellow paint at the centre. All other second quality steel trough sleepers are marked distinctly with a 15-cm-wide strip of yellow paint at one end. Sleepers that are unfit as second quality are given a distinct red paint mark to avoid mixing them up with first and second quality sleepers during loading.

7.6.3 Maintenance Problems

It has been noticed that the keys used to fix rails on steel sleepers tend to become loose due to the bending of the pressed up lugs or due to wear at the rail seat. The holes also get elongated during service. Special types of shims and liners are provided in these cases to hold the gauge well. Mota Singh Liner is a very effective type of liner used for holding the correct gauge for oblong holes with loose jaws. Another maintenance problem with steel trough sleepers is that these tend to become centre-bound if due care is not taken while packing. The ballast is normally removed from the centre of the sleepers after packing so as to ensure that centre binding of the sleepers does not take place. Sometimes the alignment of steel sleeper tracks also gets affected by the overdriving of the keys.

7.7 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

CI pot sleepers

Cast iron pot sleepers (Fig. 7.7) consist of two hollow bowls or pots of circular or elliptical shape placed inverted on the ballast section. The two pots are connected by a tie bar with the help of cotters and gibs; the gauge can be adjusted slightly [± 3 mm (1/8″)] by changing their positions. The rail is placed on top of the pots in a rail seat provided with a cant of 1 in 20 and is held in position with the help of a key. The pot sleeper suffers from the drawback that it cannot be used on curves sharper than 4° on BG. Most of the fittings are hidden and their inspection and maintenance is quite difficult. These sleepers have become obsolete now and are not being procured by the Indian Railways any more.

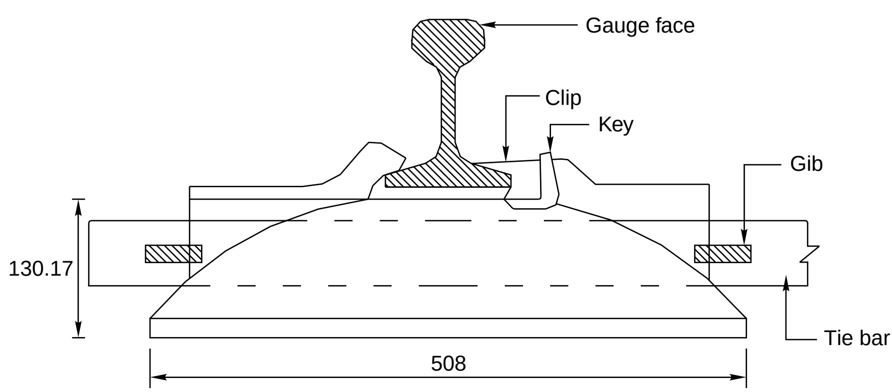


Fig. 7.7 CI pot sleeper (dimensions in mm)

CST-9 sleepers

The CST-9 sleeper is a standard sleeper and is being most extensively used on Indian Railways (IR). It is called CST-9 (Central Standard Trial-9) (Fig. 7.8) because it is the ninth of the series produced by the Central Standard Office. The sleeper is a combination of pot, plate, and box sleepers. It consists of two triangular inverted pots on either side of the rail seat, a central plate with a projected keel, and a box on top of the plate. The two CI plates are connected by a tie bar with the help of four cotters. The rails are held to the sleeper by two-way keys provided at each rail seat on the side of the gauge face. The gauge is adjusted to a value of ± 5 mm by altering the relative positions of the four cotters.

Table 7.5 Details of CST-9 sleeper (Fig. 7.9)

Rail	*Gauge*	*RDSO drawing number*	*Wt (kg)*	*A (mm)*	*B (mm)*	*C (mm)*	*D (mm)*
52 kg	BG	T-478 (M)	43.55	800	330	140	89
90 R	BG	T-478 (M)	43.55	800	330	140	89
90 R	MG	T-2366	–	700	300	132	85
75 R	MG	T-498 (M)	24.50	650	270	114	77
60 R	MG	T-10257	20.07	650	270	114	77
50 R	NG	T-438	–	533	228	108	69

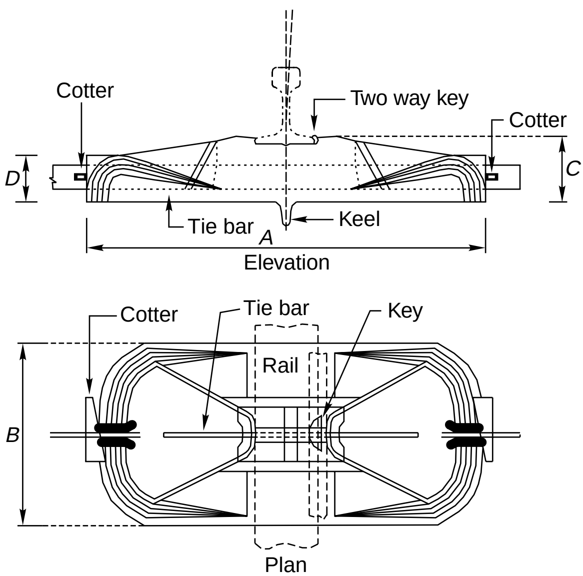


Fig. 7.8 CST-9 sleeper

The rail seat of a CST-9 sleeper is 115 mm wide along the length, and this narrow bearing tends to reduce the rocking of the sleeper under the wave motion of the rail. The sleeper is designed to provide a firm support to the rail and provides fairly good lateral and longitudinal stability to the rails. The dimensions of CST sleepers in use on IR are given in Table 7.5. The sleeper provides a bearing area approximately equal to the effective bearing area of a standard BG wooden sleeper, i.e., 5 sq. ft, for both the plates. CST-9 plates are also available with reverse jaws (T-443 type) to serve as an anti-sabotage measure; a few of these are provided in each rail length. Normally, three reverse jaw CST-9 sleepers are provided per rail to serve anti-sabotage purposes. The weight of a CST-9 sleeper assembly along with fastenings for BG is 102 kg and for MG is 58 kg.

The CST-9 sleeper is one of the most popular sleepers on Indian Railways at present. The sleeper has, however, certain limitations when combined with the modern track as mentioned in the following.

(a) As the sleeper does not have a flat bottom, it is not quite suitable for MSP and mechanical maintenance with tie tamers.
(b) The suitability of a CST-9 sleeper on LWRs, particularly on the breathing lengths, is doubtful because of rigid fastenings and the inability of the fastenings to hold the rail with a constant toe load.
(c) The rail seat wears out quickly causing the keys to come loose.
(d) The sleeper has only limited longitudinal and lateral strength to hold LWRs, particularly in the breathing length.
(e) Due to the use of less metal under rail seat, the shocks and vibrations are directly transmitted to the ballast, resulting in poor retention of packing (loose packing) and hence an increased frequency of attention.

CST-9 sleeper for MG

A new design of the CST-9 sleeper has recently been developed by Indian Railways for 90 R rails on MG lines as shown in Fig. 7.9.

CST-10 sleepers

The CST-10 sleeper is an improvement on the design of the CST-9 sleeper to suit the requirements of a modern track. The basic design feature of this sleeper is the same as that of a CST-9 sleeper except the following improvements.

(a) The rail is held with clips and double-coil spring washers instead of a fixed lug and key.
(b) An insulating liner is provided between the rail and the sleeper.
(c) A rubber pad is provided below the rail seat.

A CST-10 sleeper gives certain amount of elasticity to the track by virtue of its double-coil spring washer. The sleeper, however, has the limitation that it cannot be used with elastic fastenings.

CST-11 sleepers

The CST-11 sleeper is an improvement over the CST-10 sleeper. A special shoulder is provided to accommodate the Pandrol clip instead of clips and double-coil spring washers. An elastic rubber pad is provided between the sleeper and the rail seat instead of the rail resting directly on the sleeper. The CST-11 sleeper has the potential of being used on the modern track. The sleeper, however, is still in the experimental stage and the results are not very encouraging at present. Its design details are shown in Fig. 7.10.

CST-12 sleepers

CST-12 sleepers are designed to suit the IRN-202 clip, instead of the Pandrol clip. In this case the casting is quite complicated due to the shape of the clip. No firm has undertaken the manufacture of this sleeper as yet.

CST-13 sleepers

The purpose of the CST-13 sleeper is to use the existing CST-9 sleeper with certain additions and alternations made in the local workshop. It consists of the CST-9

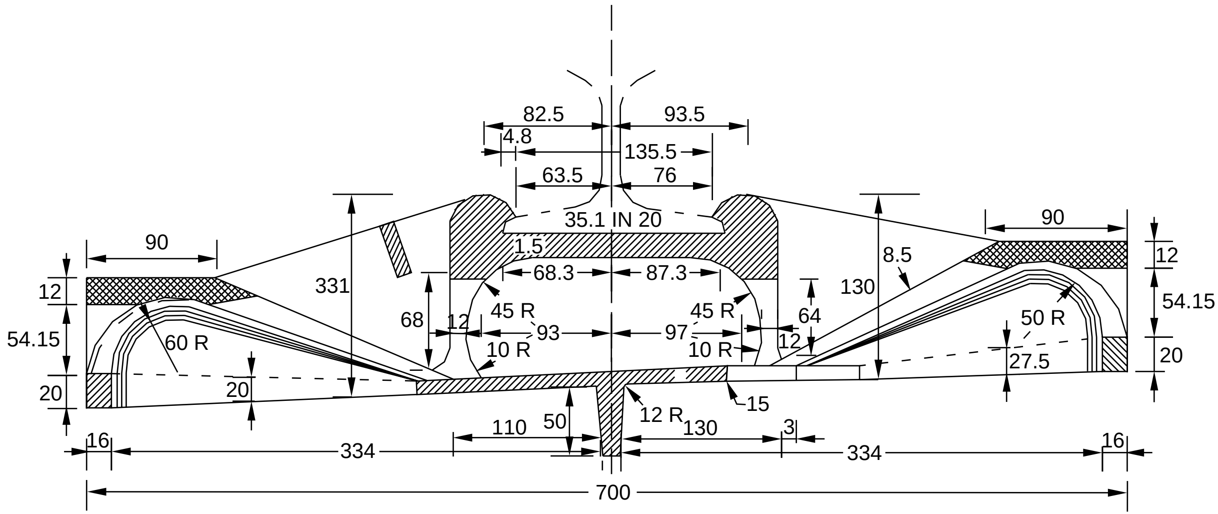


Fig. 7.9 CST-9 sleeper for MG (units in mm)

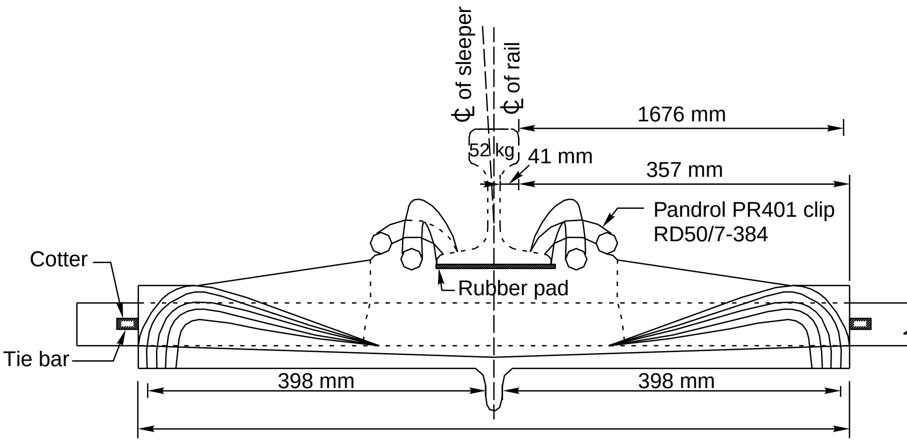


Fig. 7.10 CST-11 sleeper

plate with the rubber pad under the rail and an additional rubber head to fill the gap occupied by the key. The rail is fastened to the sleeper by a sigma clip, similar to the 'fist fastening' used on Swedish Railways. To reduce the cost of the sleeper, the inner cotter is dispensed with. No adjustment of gauge is possible in this sleeper. The CST-13 sleeper is still under trial.

7.8 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. In the year 1877, Mr Monnier, a French gardener and inventor of reinforced concrete, suggested that cement concrete could be used for making sleepers for railway tracks. Monnier in fact designed a concrete sleeper and obtained a patent for it, but his design did not work successfully. The design was further developed and the railways of Austria and Italy produced the first concrete sleepers with a promising design around the turn of the nineteenth century. This was closely followed by other European railways, where large-scale trials of concrete sleepers were done mostly due to economic considerations.

However, not much progress could not be achieved till the second world war, when wooden sleepers practically disappeared from the European market and their prices shot up. Almost at the same time, as a result of extensive research carried out by French Railways and other European railways, the modern track was born. Heavier rail sections and long welded rails came into existence. The necessity of a heavier and better type of sleeper that could fit the modern track was felt. These conditions gave a spurt to the development of concrete sleepers and countries such as France, Germany, and Britain went a long way in developing concrete sleepers to perfection.

Development

The development of concrete sleepers that took place on various railway systems was mainly based on the following concepts of design.

(a) RCC or prestressed sleepers similar in shape and size to wooden sleepers
(b) Block-type RCC sleepers connected by a steel tie bar
(c) Prestressed concrete blocks and a steel or an articulated concrete tie bar
(d) Prestressed (pre-tensioned or post-tensioned) type of concrete sleepers

These four concepts of design are the basis of the development of present-day concrete sleepers.

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.
long welded rail
(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.
measured shovel packing
(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.

Design considerations

Two different concepts are being adopted by German and French Engineers in designing the section of a concrete sleeper. The Germans, having adopted a beam type sleeper, consider the sleeper as a rigid, stiff, and continuous beam supported on a firm and unyielding bed. The French engineers however, consider the sleeper as two separate blocks connected by a tie bar and resting on a resilient ballast bed. The former design is based on static loading, while the latter theory caters for a slightly differential settlement of ballast support. As the calculations based on the latter theory are quite complicated and difficult, the sleeper design based on this concept has been evolved mostly on an empirical basis.

The forces and factors considered in the design of concrete sleepers are the following.

(a) Forces acting on a sleeper
(b) Effects of the geometric form including shape, size, and weight
(c) Effect of the characteristics of fastenings used
(d) Provision of failure against derailments

Need for concrete sleepers in India

In India there has been a chronic shortage of wooden sleepers over the last few decades. Wooden sleepers of various species in India have a short life-span of about 15–20 years. In view of this drawback of wooden sleepers, cast iron and steel trough sleepers have been used extensively. The consumption of these metal sleepers at present is quite high and Indian Railways consumes about 40% of the entire pig iron production in the country. There is a need to reduce pig iron consumption by the Railways so that the iron can be made available in large quantities for defence purposes and other heavy engineering industries. In addition, higher speeds, welding of rails, and installation of long welded rails have recently been introduced in Indian Railways. A sleeper for a long welded track has to be heavy and sturdy and should be capable of offering adequate lateral resistance to the track. Wooden and steel sleepers were found to be totally lacking in these requirements. Both these considerations led to investigations for selecting a suitable concrete sleeper for use on Indian Railways.

Loading conditions adopted by Indian Railways

Concrete sleepers have been designed by the Research Design and Standard Organization (RDSO) wing of Indian Railways for the following different loading conditions.

BG sleeper

(a) 15 t vertical loads at the rail seat.
(b) Vertical load of 15 t at rail seats plus a reaction at the centre of the sleeper equal to half of the load under the rail seat.
(c) A vertical load of 13 t and a lateral load of 7 t directed towards the outside of one rail only.

The sleeper is designed to resist a bending moment of 1.33 t m at the rail seat and 0.52 t m at the centre of the sleeper.

MG sleeper

(a) Vertical loads of 10 t at the rail seats plus a reaction at the centre of sleeper equal to half of that under the rail seat.

(b) Vertical loads of 8 t at the rail seats with 4.5 t lateral force directed towards the outside of one rail only.

7.8.1 Types

The various types of concrete sleepers (prestressed, pre-tension, post-tension, and two-block) being manufactured by Indian Railways have been described in Table 7.6.

Table 7.6 Different types of concrete sleepers being manufactured by Indian Railways

Gauge	*Type of sleeper*	*Rail section*	*Standard drawing number*	*Sleeper design number*
BG	Mono block	60 kg	RDSO/T-2496	PDS-14
BG	Mono block	52 kg	RDSO/T-2495	PDS-12
BG	Mono block	60 kg/52 kg	RDSO/T-3602	Post-tension type
BG	Mono block	90 R/75 R	RDSO/T-2521	RCS-6
BG	Mono block	90 R	RDSO/T-2503	PCS-17
MG	Twin block	75 R/60 R	RDSO/T-3518	PCS-12
BG	Twin block	75 R	RDSO/T-153	PCS-11

Mono-block prestressed concrete sleepers with pandrol clips

The mono-block prestressed concrete sleeper (Fig. 7.11), which is similar to the German B-58 type of sleeper, has an overall length of 2750 mm and a weight of 270 kg approximately. The sleeper has a trapezoidal cross section with a width of 154 mm at the top and 250 mm at the bottom and a height of 210 mm at the rail seat. A cant of 1 in 20 is provided on the top surface of the sleeper for a distance of 175 mm on either side of the centre line of the rail to cover the area of rail fittings. The sleeper is prestressed with 18 high tensile steel (HTS) strands of 3 × 3 mm diameter and 12 6-mm-diameter mild steel links. The initial prestressing of the steel is 100 kg/cm^2. The 28-day crushing strength of the concrete is normally not less than 525 kg/cm^2.

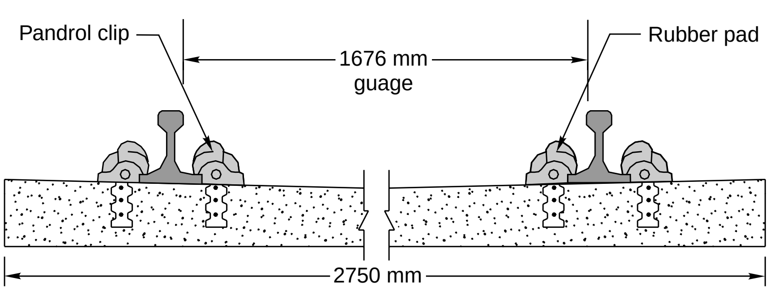


Fig. 7.11 Mono-block prestressed concrete sleeper

The rail rests on a grooved 130 × 130 mm rubber pad, with the grooves lying parallel to the axis of the rail. The fastenings provided for the 52-kg rail are Pandrol clips, which are held in malleable cast iron inserts as shown in Fig. 7.12.

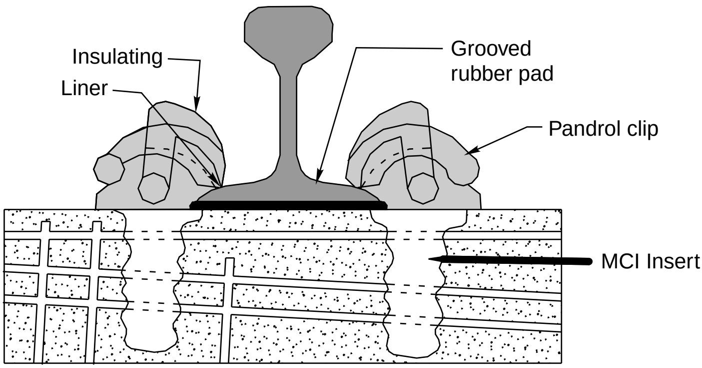


Fig. 7.12 Details at rail seat of a prestressed concrete sleeper

PCS-12 and PCS-14

PCS-12 is the latest type of prestressed concrete (PRC) sleeper for use on BG routes with 52-kg rails and elastic rail clips. For use with 60-kg rails and elastic rail clips, the PCS-14 sleeper has been standardized on Indian Railways.

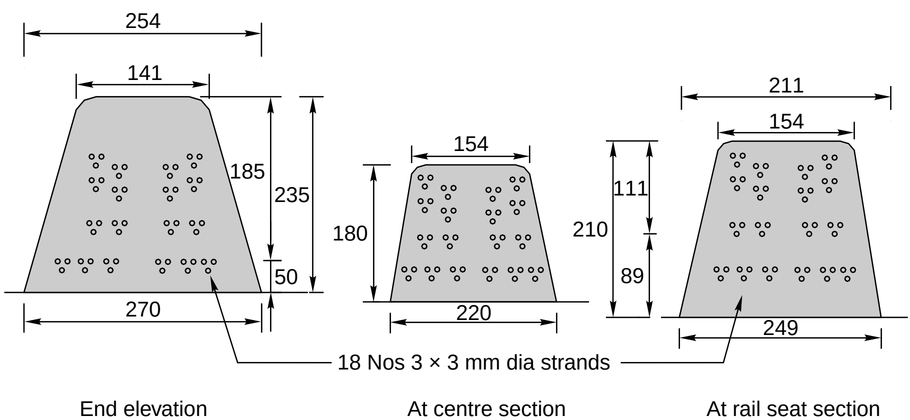


Fig. 7.13 PCS-12 mono-block concrete sleeper (units in mm)

The important dimensions of both of these types of sleepers are shown in Fig. 7.13 and listed as follows.

- Length = 2750 mm
- Weight = 267 kg
- Reinforcement: Eighteen 3 × 3 mm diameter strands
- Concrete is to be of controlled quality with a minimum 28-day crushing strength of 525 kg/cm^2
- Each strand to be tensioned with an initial tensile force of 2730 kg

Mono-block post-tension type of concrete sleepers for BG

The first factory in India for the manufacture of post-tension type of mono-block concrete sleepers was set up by Northern Railways at Allahabad in collaboration with M/s Dyckerhoff and Widmann (D&W) of West Germany. The factory, which started production in 1981, has a planned capacity of manufacturing 300,000 concrete sleepers per year. The salient feature of post-tension type of concrete sleepers are the following.

Size of sleeper

- Length = 2750 mm
- Width at centre = 160 mm (top)
  200 mm (bottom)
- Depth at centre = 180 mm
- Weight = 295 kg

Design features

- Initial prestressing force = 37 t
- Final prestressing force = 31 t
- Minimum concrete strength in 28 days = 550 kg/cm^2
- Minimum strength of concrete at the time of applying prestress = 450 kg/cm^2

The use of concrete sleepers using the post-tension method has not been successful on Indian Railways and its manufacture has since been stopped.

Mono-block PRC sleepers for MG (PCS-17)

A design for mono-block PRC sleepers (PCS-17) has recently been standardized for MG. The sleeper has a trapezoidal cross section similar to that of a BG sleeper. The concrete should have a 28-day compressive strength of 525 kg/cm^2. The salient features of this sleeper are the following (Fig. 7.14).

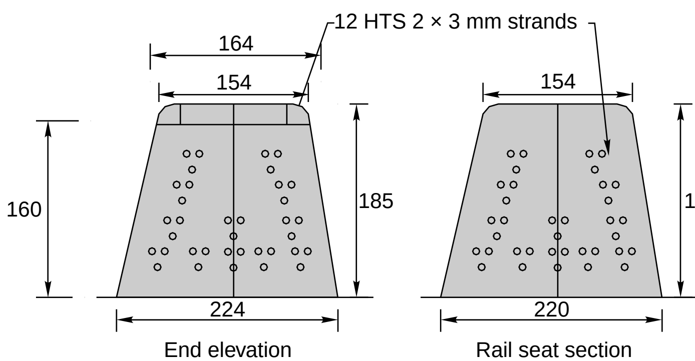


Fig. 7.14 PCS-17 concrete sleeper for MG (units in mm)

- Length = 2000 mm
- Weight = 158.5 kg
- Reinforcement: Twelve 3 × 3 mm diameter strand of HTS wire tensioned to initial force of 2730 kg

PRC sleepers can be used for 90 R rails with elastic rail clips and glass filled nylon liners (GFN 66) and on sole plates.

Two-block RCC sleeper for BG yards

A design for a two-block RCC sleeper for BG yards has been standardized by RDSO as per drawing number RDSO/T-2521 for extensive trials on Indian Railways. There is a general scarcity of wooden and CST-9 sleepers for use in BG yards and the new RCC sleepers will ease the situation in a big way. Some of the salient features of this sleeper are as follows.

- Considering low speeds in yard lines and less impact effect, the rail seat design load has been taken only as 10 t without any lateral thrust.
- Size at rail seat (top width × bottom width × depth) = 22 cm × 30 cm × 17 cm
- Overall length of the sleeper = 247.5 cm
- Weight of the sleeper = 170 kg
- Main reinforcement in each block
  - At top: Five 8-mm-diameter steel bars
  - At bottom: Two 8-mm-diameter steel bars
- The fastenings used are steel clips and a spring washer with screw fitted to a polythene dowel.

Two-block concrete sleeper for MG yards

Two-block concrete sleepers for use in MG yards have recently been developed. The sleeper consists of two cement concrete blocks, each weighting about 36 kg and consisting of an MS reinforcement of about 7 kg. The two RCC sleeper blocks are connected by an angle tie bar of 55 × 50 × 6 mm section and 1.5 m length. The rail is fixed to the sleeper block either by a clip and bolt arrangement or by polythene dowels and rail screws. A pad is provided below the rail seat to provide cushioning.

Mono-block versus two-block concrete sleepers

There are relative advantages and disadvantages of mono-block and two-block concrete sleepers. Some of these are enumerated below.

(a) Mono-block sleepers give better longitudinal and lateral stability to the track compared to two-block concrete sleepers.

(b) The mono-block concrete sleeper, being a monolithic concrete mass, is likely to have a longer working life compared to the two-block concrete sleeper connected with a tie bar. In the latter case, a tie bar is weak and has a comparatively shorter life due to corrosion, etc.

(c) The mono-block concrete sleeper requires heavy capital expenditure for its manufacture, being a prestressed reinforced concrete unit, compared to the two-block sleeper, which is an ordinary reinforced concrete sleeper.

(d) In a mono-block prestressed concrete sleeper, a crack that develops because of overstressing is likely to close down upon return to normal condition, whereas in a two-block sleeper, such a crack will continue to remain open.

(e) Mono-block sleepers are likely to become centre-bound unlike two-block sleepers.

(f) During derailments and rough handling the tie bars of two-block sleeper get deformed, thereby affecting the gauge.
(g) In a two-block sleeper, the two blocks are not likely to rest on the ballast in a way that each rail is properly inclined to the vertical, a feature which could affect the alignment and gauge of the track.

7.8.2 Sleepers for Turnouts

A railroad turnout is a mechanical installation that enables trains to be guided from one line of rail tracks to another. In this section we discuss sleepers and sleeper designs for turnouts.

Prestressed concrete sleepers for turnouts

Due to the acute shortage of wood, especially of long timbers required for points and crossings, it was felt necessary to develop PRC sleepers for use on turnouts in track-circuited areas. RDSO developed a PRC sleeper design with a rectangular cross section in July 1986 for 1 in 12 left-hand turnouts with a 7730-mm curved switch for use with 52-kg rails. These PRC sleepers for turnouts have been manufactured in the PRC sleeper factory at Khalispur, and these sleepers are on trial on Northern Railways at present. The salient features of these sleepers are the following.
(a) The sleepers have a rectangular cross section.
(b) There are 74 sleepers comprising 2l sleepers in switch assembly, 3 in intermediate sub-assembly and 18 in crossing sub-assembly.
(c) The sleepers are of varying lengths and design. There are 16 different turnout sleeper designs.
(d) These sleepers require the use of a number of fittings different from the existing standard fittings. The grooved rubber pads are of a standard 4.5 mm thickness, but of varying size.

New fan-type concrete sleeper for turnouts

The prestressed concrete sleepers discussed above are suitable only for 1 in 12 turnouts. RDSO has developed a new fan-type sleeper that can be used for 1 in 8.5 as well as 1 in 12 turnouts.

The new design of concrete sleepers has the following characteristics.
(a) The cross section of the sleeper in the new design is trapezoidal instead of rectangular as in the earlier design.
(b) The layout of the sleepers is fan shaped and the same design of sleepers can be used for right-hand as well as left-hand turnouts by rotating them 10° in a horizontal plane.
(c) Apart from approach sleepers, 54 concrete sleepers are used for 1 in 8.5 turnouts and 83 concrete sleepers are used for 1 in 12 turnouts.
(d) The concrete used has a 28-day crushing strength of 600 kg/cm^2.
(e) The sleepers are laid perpendicular to the main line on the switch portion. In the lead portion, sleepers are laid equally inclined to the straight and turnout tracks. In the crossing portion, the sleepers are laid perpendicular to the bisecting line of the crossing.

(f) The sleepers under the switch portion have dowels for fixing slide chairs with the help of screws. These sleepers are laid perpendicular to the main line and, therefore, can be used for both left-hand and right-hand turnouts.

(g) The mark 'RE' is provided on the fan-shaped PRC turnout sleepers at one end. The sleepers should be so laid that the end with the RE mark is always laid on the right-hand side.

Laying of the concrete sleepers on turnouts

The turnout locations where concrete sleepers are to be laid should have a clean ballast cushion of 30 cm thickness. Extra ballast should be available on the cess and the area should have good drainage. Depending upon the availability of space and various other site conditions, one of the following three methodologies or their combinations can be adopted for laying concrete sleeper turnouts.

- Assembling the turnout at the site and replacing it during the block period by means of either cranes or rollers.
- Carrying parts of the assembled turnout on dip lorries and replacing them during the block period.
- Replacing the existing turnout sleeper by sleeper except for the switch portion, which can be assembled as one unit.

The assembling and laying should normally be done using a crane of suitable capacity. After removing old turnout sleepers, the ballast bed at the level of the bottom of the concrete sleepers for turnouts should be evened out. Vibrating rollers should be employed to the extent possible for compaction of ballast bed.

Turnouts with concrete sleepers can be maintained in any one of the following ways:

(a) using points and crossing tamper,

(b) using off-track tampers with lifting jacks, or

(c) measured shovel packing.

In the case of emergencies such as derailments, when the sleepers may be damaged, temporary repairs should be carried out by interlacing wooden sleepers for permitting traffic with restricted speed. The damaged concrete sleepers are replaced by a fresh lot of turnout concrete sleepers as a permanent measure as early as possible. The wooden sleepers and any other damaged sleepers are replaced one by one with new turnout sleepers.

7.8.3 Manufacture

Prestressed concrete sleepers can be of the pre-tensioned or post-tensioned type. In the case of pre-tensioned sleepers, the force is transferred to the concrete through bonds or through a combination of bonds and positive anchors. Bond transmission lengths and the losses in prestress vitally affect the design and determine the quality of manufacture. In the post-tensioned type of sleeper, the force is transferred only through positive anchors.

Mono-block prestressed

Mono-block concrete sleepers are generally manufactured by the ‘long line method’. In this method, at a time, 30–40 moulds for casting concrete sleepers are kept in about 100–120-m-long casting beds. High tensile steel wires with diameters of 5 mm are anchored at the end block between the tension towers and moulds, and stretched by a specially designed tensioning method. The tensile stress in the wires should not exceed 70% of the specified minimum UTS (ultimate tensile stress). High-quality concrete, with a pre-designed mix, is then filled into the moulds. The newly laid cement concrete is thoroughly mixed and consolidated by means of high-frequency vibrators. The concrete is then cured after about 3 hours, preferably by steam. The wires are then destressed by Hover’s method of destressing. The wires are cut and the line is released. The sleepers are further cured by submerging them into a water tank for a period of 14 days. Alternatively, the sleepers can also be steam cured.

Another method adopted sometimes for the manufacture of prestressed mono-block concrete sleepers is the short line method or ‘stress bench method’. This process involves the use of short stress benches that accommodate 4–5 sleepers. The ends of the benches serve as anchor plates and comprise an iron frame to bear the initial prestressing force. The benches are on wheels and are mobile. The prestressing is done as in the case of the long line method. The concreting, vibrating, etc. is, however, done at a fixed place, the stress benches being moved into position one after another. This leads to better quality control in concrete mixing and compaction. Generally, after casting the benches are taken into steam chambers for curing with an overall turnround period of about 24 hours and a steam curing cycle of about 16 hours. This method of manufacture gives qualitatively better results and has been adopted by M/s Daya Engineering Works Pvt. Ltd, Gaya, and M/s Concrete Products and Construction Co., Chennai.

Prestressed mono-block concrete sleepers can also be manufactured by the individual mould method. This method is generally used when prestressing is transferred to concrete through bonds and positive anchorages in the case of pre-tensioned sleepers or only by positive anchors in the case of post-tensioned sleepers. The mould for the pre-tensioned type is designed to take the initial prestressing force and hence has to be sturdier than the moulds used in other systems. The moulds can adjust one to three sleepers, and as they move along the assembly line, various tasks, such as cleaning of moulds, insertion of high tensile stress wires, prestressing of wires, fixing inserts, concreting, vibrating, steam curing, and remoulding, are carried out on the manufacturing belt. This system involves a greater degree of automation, yields qualitatively better results, and requires the least amount of work force. In India, factories utilizing this technique have currently gone into production at Secunderabad and Bharatpur.

Two-block

The manufacture of two-block concrete sleepers is simple and similar to that of any other ordinary precast RCC unit. These sleepers are manufactured in a mould in which the necessary reinforcement and tie bar are placed in position. Concrete of designed mix is then poured into the mould and vibrated. The mould is removed after the concrete is set and the blocks are cured in water for a period of 14 days.

Post-tension

Post-tension type of concrete sleepers were earlier manufactured in the concrete sleeper plant at Allahabad as per the design submitted by D&W of Germany, which was approved by the Railway Board. The specialty of this patent design of D&W lies in the use of high tensile steel rods bent into the U shape known as 'hair pins', slits, and nuts. This process also involved the instantaneous demoulding of the products.

The technology of post-tension concrete sleepers has become outdated over time. The sleepers manufactured in the concrete sleeper plant (CSP) at Allahabad have been quite uneconomical and their rejection rate has also been quite high. In view of this, the manufacture of concrete sleepers by the post-tension method has been stopped in the CSP at Allahabad since July 1995.

7.8.4 Testing

In addition to the control checks exercised on the material and manufacturing process, the concrete and the finished sleepers are subjected to the following periodical checks and tests.

(a) The minimum 28-day compressive strength of the test cube should not be less than 525 kg/cm^2. Sleepers from occasional batches in which the minimum crushing strength falls below 525 kg/cm^2 but not below 490 kg/cm^2 may be accepted subject to their passing the increased frequency of testing for static bending strength.

(b) The minimum compressive strength of the test cube of concrete at detensioning should not be less than 370 kg/cm^2.

(c) The modulus of rupture should be as specified in the Concrete Bridge Code.

(d) The dimensional tolerance and surface finish of the sleepers should be checked using suitable templates and gauges.

(e) The cracking and failure moments of the sleepers should be tested at the following sections by applying suitable loads:
   - (a) Positive cracking moment at rail seat bottom
   - (b) Negative cracking moment at centre section top
   - (c) Positive cracking moment at centre section bottom
   - (d) Failure moment at rail seat bottom

(f) For the abrasion resistance test, the concrete sleeper is subjected to a vibrating load under specified conditions. After 300 hours of operating time, the loss in weight due to abrasion should not be more than 3%.

7.8.5 Handling

Concrete sleepers weigh about 215 to 270 kg and about 6 to 8 persons are required to handle one sleeper. The mechanical handling of concrete sleepers is, therefore, desirable for safety purposes.

7.8.6 Prohibited Locations

Concrete sleepers, because of their heavy weight and rigidity of structure, are not suited to yielding formations, fish-plated joints, and places where uniform packing cannot be achieved. Concrete sleepers as such are normally laid at only those locations where LWRs are permissible. These sleepers should not be laid at the following locations:

(a) New formation in banks unless specially compacted
(b) Any rock cuttings, except where a minimum depth of 300 mm of ballast cushion has been provided
(c) Un-ballasted lines in yards
(d) Curves of radius less than 500 m
(e) Troublesome formations
(f) Near ashpits and other locations where drivers habitually drop ash
(g) At locations where excessive corrosion is expected
(h) On un-ballasted bridges and on arch bridges, where the height between the arch and the bottom of the ballast section is less than 1 m, and on slab bridges, where the ballast cushion between the bottom of the sleepers and the top of the slab is less than 300 mm
(i) With fish-plated tracks. Should be used only with long welded rails. Fish-plated joints on concrete sleeper tracks, where unavoidable, should have wooden sleepers at joints.

7.8.7 Laying

Concrete sleepers are heavy, and as such manual handling of concrete sleepers is not only difficult, but may generally damage the sleeper as well. In exceptional cases, however, manual handling, including manual laying of concrete sleepers, is resorted to after taking adequate precautions.

In the case of the mechanical relaying system, normally two portal cranes are used on Indian Railways and relaying is done using prefabricated panels. The existing rail panels are removed by gantry cranes, the ballast is levelled up, and prefabricated panels are then laid with the help of portal cranes. The following operations are involved.

(a) Preparation work at the site of relaying
(b) Pre-assembly of panels in base depots
(c) Actual relaying operation
(d) Post-relaying work

The full details of the manual relaying method as well as of the mechanical relaying system are given in Chapter 21.

7.8.8 Maintenance

The following points need attention in the maintenance of concrete sleepers.

(a) Concrete sleepers should normally be maintained with heavy on-track tampers. For spot attention, MSP or off-track tampers may be used. The size of chips for MSP should be 8 mm–30 mm as required

(b) Only 30 sleeper spaces are to be opened out at a time between two fully boxed track stretches of 30 sleepers length each in case a LWR track exists.

(c) Concrete sleepers should be compacted well and uniformly to give a good riding surface. Centre binding of mono-block concrete sleepers should be avoided, for which the central 800 mm of the sleeper should not be hard packed.

(d) Both ends of the concrete sleepers should be periodically painted with anticorrosive paint to prevent corrosion of the exposed ends of prestressing wires. In the case of two-block sleepers, the tie bars should be examined every year, and if any sign of corrosion is noticed, the affected portion should be painted with an approved paint.

(e) Mechanical equipment should be used for laying and maintaining concrete sleepers as far as possible.

(f) Wherever casual renewal of concrete sleepers is to be done, the normal precautions followed for LWR tracks should be taken.

(g) The elastic rail clip should be driven properly to ensure that the leg of the clip is flush with the end face of the insert. Overdriving and underdriving should be guarded against, as these cause eccentric loading on the insulations, resulting in their displacement and in the variation of load.

(h) A vigilant watch should be kept to ensure that no creep occurs in any portion of the concrete sleeper track or there is no excessive movement near the switch expansion joint (SEJ).

(i) It must be ensured that the rubber pads are in their correct positions. Whenever it is found that the rubber pads have developed a permanent set, these should be replaced by new ones. Such examinations can be done at the time of destressing. Toe load can also be lost due to ineffective pads.

(j) Nylon or composite insulating liners used with Pandrol clips should be examined periodically for signs of cracking and breakage. Adequate care should be exercised when driving the clip at the time of installation to prevent damage.

(k) One of the biggest problems regarding the maintenance of a concrete sleeper track is that the elastic rail clips get seized with malleable cast iron (MCI) inserts not only during regular maintenance, but also during destressing, other incidental works, and derailments. The following remedial measures are suggested.

  (i) At the base depot, all the elastic rail clips and MCI inserts should be thoroughly cleaned. Grease should then be applied on the central leg of the elastic rail clip (ERC) and the eye of the MCI insert. These should then be driven into place at the time of assembly of the service pan.

  (ii) During service all the elastic rail clips must be taken out from the MCI inserts and cleaned with a wire brush and emery paper, specially on the central leg. The eyes of the MCI inserts must also be cleaned of any debris or rusted material. The central leg of the ERC should then be covered with good quality grease. The eyes of the MCI inserts should be smeared with the same grease before the treated ERCs are driven back. This has to be repeated every one year in corrosion prone areas. A maintenance checklist for concrete sleepers is given in Table 7.7.

Table 7.7 Maintenance checklist for concrete sleepers

Item	*Points for checking*
Location of concrete sleepers	▸ Concrete sleepers should normally be laid on a LWR/ CWR track, first preference being given to high-speed routes and then to other routes. The track standard for the use of a concrete sleeper has been specified in chapter 5. ▸ Concrete sleepers should be used only at permitted locations. See section 7.8.6.
Sleeper spacing	▸ Spacing should be uniform, 60 cm for a sleeper density of 1660/km and 65 cm for a sleeper density of 1540/km.
Ballast section	▸ The specified ballast section for LWR should be followed. ▸ In two-block RCC sleepers, a 1033-mm-wide central trough should be provided to avoid corrosion of the tie bar.
Handling of concrete sleepers	▸ Preferably mechanized means such as gentry cranes should be used. In exceptional cases, manual handling should be done using sleeper slings and rail dollies, taking proper precautions to avoid damage to the sleeper.
Laying concrete sleepers	▸ Mechanical means, i.e., portal cranes with a pre-assembled panel should be adopted. ▸ Manual laying should be adopted only in exceptional conditions and that too with proper precautions.
Maintenance of concrete sleepers	▸ On-track tampers should be used for regular maintenance of long stretches. ▸ Off-track tampers such as Chinese tampers or measured shovel packing should be used for isolated or short stretches. ▸ In emergencies, a blunt end beater should be used for packing.
Maintenance of fastenings used with concrete sleeper track	▸ Overdriving or underdriving of Pandrol clips should be guarded against. ▸ It should be ensured that the rubber pad is in its correct position and renewed when these develop permanent set. ▸ Care should be taken while driving the clip into position to avoid damage to liners. Cracked liners should be replaced. ▸ At the time of initial laying as well as during service, all the MCI inserts and ERCs should be thoroughly cleaned and then grease applied on the central leg of ERC and the eye of the MCI insert.

7.8.9 Derailment

Derailment is a kind of accident that occurs when the wheels of a vehicle mount the rail head. It causes excessive damage to the track in general and sleepers in particular.

The following actions should be taken in the eventuality of a derailment on a track with concrete sleepers.

(a) When the damage to concrete sleepers is not extensive and it is possible to allow the traffic to pass at a restricted speed, suitable speed restriction should be imposed after assessing the damage to the track. Sleepers should be replaced as in the case of casual renewals while taking all precautions. After all the damaged sleepers are replaced, the affected portion as well as the portions 100 m on either side adjacent to it should be distressed, and normal speed should be restored after consolidation.

(b) When the damage to the concrete sleeper is extensive and the track is distorted in such a way that it is not possible to allow traffic to pass even at a restricted speed, the affected portion should be isolated by introducing buffer rails on either end of it. The distorted track should be removed and replaced by the track laid on single-rail panels using the available rails and sleepers. The section should then be converted into long welded rails using concrete sleepers, taking the usual precautions laid down in the LWR manual.

7.8.10 Concrete Sleepers on Indian Railways

Indian Railways is modernizing its track in a big way to meet the challenges of heavier traffic at faster speeds. The modern track consisting of long welded 52-kg/60-kg rails, concrete sleepers, and elastic fastenings can meet the above requirements.

Prestressed concrete sleepers are most economical and technically best suited for high speeds and heavy traffic density. They provide a stable track structure, which requires less maintenance efforts. Maintenance of concrete sleepers track should, however, be done using track machines only.

It has been proposed that concrete sleepers should be provided on all important routes of Indian Railways. Adequate capacity has been developed for the production of these sleepers to meet all the requirements of IR. During 2003–04, 8.86 million concrete line sleepers (highest ever production) and 3426 sets of concrete turnout sleepers were produced. The intake of wooden sleepers for main lines has been completely stopped and emphasis is being laid on using concrete sleepers on turnouts.

Indian Railways is the world leader in the manufacture of concrete sleepers and is presently manufacturing about 60% of the total concrete sleepers in the world. These concrete sleepers have a very bright future on Indian Railways.

Summary

Sleepers support rails and transfer the live load of moving trains to the ballast and formation. Wooden sleepers are the best, as they satisfy almost all the requirements of an ideal sleeper. Scarcity of timber has led to the development of metal and concrete sleepers. Concrete sleepers have high strength and a long life, and are most suitable for modern tracks. Indian Railways has developed designs for prestressed concrete sleepers and these are being extensively used on all important routes.

Review Questions

1. What are the requirements of sleepers used in a railway track? Give a neat sketch of a typical BG mono-block prestressed sleeper. What are its advantages and drawbacks?
2. List the various types of sleepers used on Indian Railways. Which one would you consider to be the best for modern tracks and why?
3. Enumerate the loading conditions adopted by RDSO for the design of mono-block prestressed concrete sleepers in India.
4. List the various types of metal sleepers in use on Indian Railways. Describe mono-block prestressed concrete sleepers with a neat sketch. What are the reasons for their ever-increasing adoption the world over?
5. Using a sleeper density of $N + 5$, determine the number of sleepers required for the construction of a 1800-m BG track. (***Ans***: 100)
6. Discuss the factors on which sleeper density depends. How is sleeper density expressed? Determine the number of sleepers required for the construction of a 640-m-long BG railway track, ensuring a sleeper density of $(N + 7)$. (***Ans***: 32)
7. Compare the characteristics of the different types of sleepers used in our country.
8. Compare the characteristics of wooden sleepers and reinforced concrete sleepers used on Indian Railways.
9. Explain the functions of sleepers and ballast in a railway track. Explain how the spacing of sleepers is determined. Give specific reasons for the necessity of regular maintenance of the ballast.
10. Draw a neat sketch of the prestressed concrete sleeper used on Indian Railways for broad gauge tracks. Give details of the location of wires and the seating and fastening arrangements.
11. What are the different types of sleepers used in the track on Indian Railways? Write down in brief the advantages and disadvantages of each type.
12. What are the advantages and disadvantages of steel trough sleepers? What is the function of tie bars in the case of cast iron pot sleepers? What is the relation between sleeper density and the width of ballast?
13. What is the difference between treated and untreated wooden sleepers? Describe briefly the use and methods of treatment of wooden sleepers being adopted on Indian Railways.
14. What are the loading conditions adopted by Indian Railways for the design of concrete sleepers? Discuss briefly the relative advantages and disadvantages of mono-block sleepers two-block sleepers.
15. What are the various methods of manufacture of concrete sleepers? Discuss briefly one of these methods on Indian Railways.
16. What is the future scope of concrete sleepers on Indian Railways? Discuss briefly the planning being done for the production of concrete sleepers in India.

CHAPTER
8

Ballast

Introduction

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. Different types of ballast materials and their specifications are discussed in this chapter.

8.1 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.

8.2 Types of Ballast

The different types of ballast used on Indian Railways are described in the following.

Sand ballast

Sand ballast is used primarily for cast iron (CI) pots. It is also used with wooden and steel trough sleepers in areas where traffic density is very low. Coarse sand is preferred in comparison to fine sand. It has good drainage properties, but has the drawback of blowing off because of being light. It also causes excessive wear of the rail top and the moving parts of the rolling stock.

Moorum ballast

The decomposition of laterite results in the formation of moorum. It is red, and sometimes yellow, in colour. The moorum ballast is normally used as the initial ballast in new constructions and also as sub-ballast. As it prevents water from percolating into the formation, it is also used as a blanketing material for black cotton soil.

Coal ash or cinder

This type of ballast is normally used in yards and sidings or as the initial ballast in new constructions since it is very cheap and easily available. It is harmful for steel sleepers and fittings because of its corrosive action.

Broken stone ballast

This type of ballast is used the most on Indian Railways. A good stone ballast is generally procured from hard stones such as granite, quartzite, and hard trap. The quality of stone should be such that neither is it porous nor does it flake off due to the vagaries of weather. Good quality hard stone is normally used for high-speed tracks. This type of ballast works out to be economical in the long run.

Other types of ballast

There are other types of ballast also such as the brickbat ballast, gravel ballast, kankar stone ballast, and even earth ballast. These types of ballast are used only in special circumstances.

The comparative advantages, disadvantages, and suitability of different types of ballast are given in Table 8.1.

Table 8.1 Comparison of different types of ballast

Type of ballast	*Advantages*	*Disadvantages*	*Suitability*
Sand ballast	▸ Good drainage properties ▸ Cheap ▸ No noise produced on the track ▸ Good packing material for CI sleepers	▸ Causes excessive wear ▸ Blows off easily ▸ Poor retentivity of packing ▸ Track cannot be maintained to high standards	▸ Suitable for CI pot sleeper tracks ▸ Not suitable for high-speed tracks
Moorum ballast	▸ Cheap, if locally available ▸ Prevents water from percolating ▸ Provides good aesthetics	▸ Very soft and turns into dust ▸ Maintenance of track the difficult ▸ Quality of track average	▸ Used as a sub-ballast ▸ Initial ballast for new construction

(*contd*)

Table 8.1 (*contd*)

Type of ballast	*Advantages*	*Disadvantages*	*Suitability*
Coal ash or cinder	▸ Easy availability on railways ▸ Very cheap	▸ Harmful for steel sleepers ▸ Corrodes rail bottom and steel sleepers	▸ Normally used in yards and sidings ▸ Suitable for repairs of formations during floods and emergencies
	▸ Good drainage	▸ Soft and easily pulverized ▸ Maintenance is difficult	▸ Not fit for high-speed tracks
Broken stone ballast	▸ Hard and durable when procured from hard rocks	▸ Initial cost is high	▸ Suitable for packing with track machines
	▸ Good drainage properties ▸ Is stable, and resilient to the track ▸ Economical in the long run	▸ Difficulties in procurement ▸ Angular shape may injure wooden sleepers	▸ Suitable for high-speed tracks

8.3 Sizes of Ballast

Previously, 50-mm (2″) ballasts were specified for flat bottom sleepers such as concrete and wooden sleepers and 40-mm (1.5″) ballasts were specified for metal sleepers such as CST-9 and trough sleepers. Now, to ensure uniformity, 50-mm (2″) ballasts have been adopted universally for all type of sleepers.

As far as points and crossings are concerned, these are subjected to heavy blows of moving loads and are maintained to a higher degree of precision. A small sized, 25-mm (1″) ballast is, therefore, preferable because of its fineness for slight adjustments, better compaction, and increased frictional area of the ballast.

8.4 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 easily available.

8.5 Design of Ballast Section

The design of the ballast section includes the determination of the depth of the ballast cushion below the sleeper and its profile. These aspects are discussed below.

8.5.1 Minimum Depth of Ballast Cushion

The load on the sleeper is transferred through the medium of the ballast to the formation. The pressure distribution in the ballast section depends upon the size and shape of the ballast and the degree of consolidation. Though the lines of equal pressure are in the shape of a bulb, yet for simplicity, the dispersion of load can be assumed to be roughly 45° to the vertical. In order to ensure that the load is transferred evenly on the formation, the depth of the ballast should be such that the dispersion lines do not overlap each other.

For the even distribution of load on the formation, the depth of the ballast is determined by the following formula (refer to Fig. 8.1):

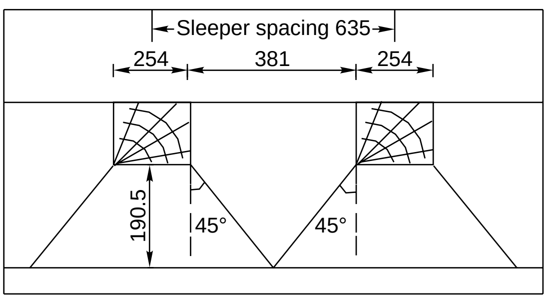


Fig. 8.1 Minimum depth of ballast cushion (dimensions in mm)

$$\text{Sleeper spacing} = \text{width of the sleeper} + 2 \times \text{depth of ballast} \tag{8.1}$$

If a BG track is laid with wooden sleepers with a sleeper density of $N + 6$, then the sleeper spacing would be 68.4 cm. If the width of the sleeper is 25.4 cm, then the depth of the ballast cushion would be

$$d = \frac{68.4 - 25.4}{2} = 21.5 \text{cm}$$

A minimum cushion of 15–20 cm of ballast below the sleeper bed is normally prescribed on Indian Railways.

8.5.2 Ballast Profile for Fish-plated Track

The ballast profile for a fish-plated track is shown in Fig. 8.2. The requirements of ballast for different groups of railway lines as adopted by Indian Railways are given in Table 8.2.

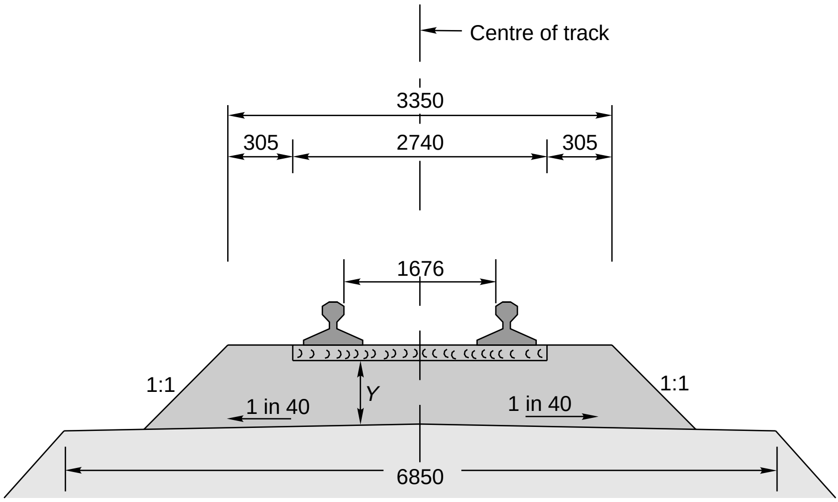


Fig. 8.2 Standard ballast profile for BG (Other than LWR/CWR)

Table 8.2 Ballast requirement for fish-plated tracks

Group	*Recommended depth of ballast cushion Y (mm)*	*Quantity of ballast required/metre*	
		On straight lines and curves of radius greater than 600 m (m^3)	*On curves of radius lower than 600 m (m^3)*
A	300*	1.588	1.634
B and C	250	1.375	1.416
D	200	1.167	1.202
E	150	0.964	0.996

* In the case of ordinary fish-plated tracks, to be increased on the outside of the curves to 400 mm in the case of sharper curves of a radius more than 600 m. In short welded panel tracks, it is to be increased to 400 mm on the outside of all curves flatter than 875 m and to 450 mm in the case of sharper curves with a radius more than 875 m. To be increased to 550 m on the outside of the turn on curves of turnouts in passenger yards. In the case of a short welded rail (SWR) track, the minimum depth of cushion should be 200 mm.

8.5.3 Ballast Profile for Long Welded Rail Tracks

The ballast profile for a long welded rail (LWR) track is shown in Fig. 8.3. The requirements of ballast for different types of sleepers on a BG railway line are given in Table 8.3.

The minimum clean stone ballast cushion below the bottom of sleeper (*A*) is 250 mm. For routes where speeds are to be more than 130 kmph, *A* is 300 mm–200 mm along with 150 mm of sub-ballast. Suitable dwarf walls should be provided in the case of cuttings, if necessary, for retaining the ballast.

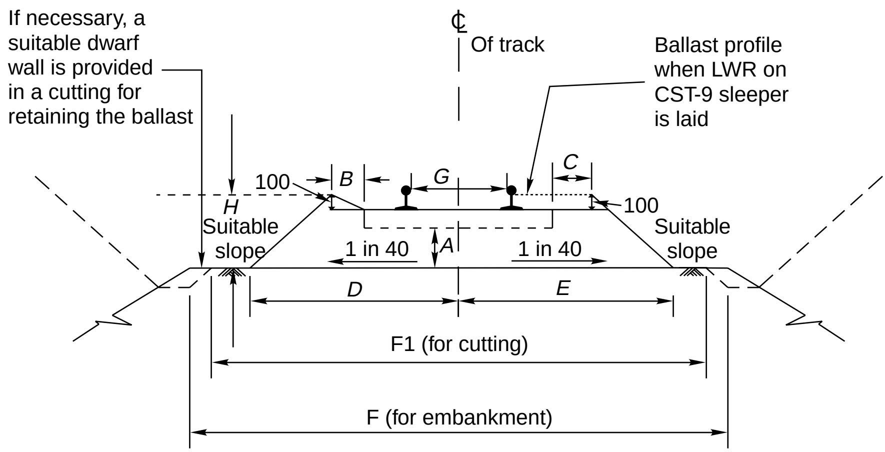


Fig. 8.3 Ballast profile for LWR track (single line BG)

Table 8.3 Ballast requirement (mm) for single-line BG LWR tracks

Type of sleeper	*A*	*B*	*C**	*D*	*E**	*F*	*F1*	*H*	*Quantity of ballast per metre (m³)*	
									Straight track	*Curved track*
Wooden	250	350	500	2270	2420	6850	6250	540	1.682	1.646
	300	350	500	2270	2420	6850	6250	590	1.782	1.853
	†	350	500	2270	2420	6850	6250	640	1.982	2.060
Steel trough	250	350	500	2270	2430	6850	6250	550	1.762	1.827
	300	350	500	2270	2440	6850	6250	600	1.962	2.035
	†	350	500	2270	2430	6850	6250	650	2.162	2.242
Prestressed concrete	250	350	500	2270	2510	6850	6250	630	1.954	2.032
	300	350	500	2270	2510	6850	6250	680	2.158	2.243
	†	350	500	2270	2510	6850	6250	730	2.362	2.455
Two-block	250	350	500	2270	2510	6850	6250	630	2.110	2.193
	300	350	500	2270	2510	6850	6250	680	2.314	2.405
	†	350	500	2270	2510	6850	6250	730	2.518	2.616

* On the outer side of the curves only. Cess may be widened where required depending on local conditions and the outer ends of the curves.
† 200 mm over 150 mm sub-ballast.

8.6 Specifications for Track Ballast

The following specifications of ballast, which have recently been revised (June 2004), are followed on Indian Railways. These specifications are applicable for the stone ballast to be used for all types of sleepers on normal tracks, turnouts, tunnels, and deck slabs on all routes.

8.6.1 General Qualities

The ballast material should possess the general qualities described below.

Basic quality The ballast should be hard, durable, as far as possible angular along edges/corners, and free from weathered portions of parent rock, organic impurities, and inorganic residues.

Particle shape Ballasts should be cubical in shape as far as possible. Individual pieces should not be flaky and should have flat faces generally with not more than two rounded/sub-rounded faces.

Mode of manufacture Ballasts for all BG main lines and running lines, except on E routes, but including E special routes, should be machine crushed. For other BG lines and MG/NG routes planned or sanctioned for conversion, the ballast should preferably be machine crushed. Hand broken ballast can be used in exceptional cases with the prior approval of the chief track engineer or the CAO (chief administrative officer). Such approval should be obtained prior to the invitation of tenders. Hand broken ballasts can be used without any formal approval on MG and NG routes not planned or sanctioned for conversion.

8.6.2 Physical Properties

All ballast samples should possess the physical properties given in Table 8.4 when tested in accordance with IS:2386 (IV)–1963.

Table 8.4 Physical requirements of ballast

Characteristics	*BG, MG, and NG (planned/sanctioned for conversion)*	*NG and MG (other than those planned for conversion)*
Aggregate abrasion	30% maximum*	35% maximum
Aggregate impact	20% maximum*	30% maximum
Water absorption	1%	–

* In exceptional cases, relaxable on technical and/or economic grounds up to 35% and 25%, respectively, by the chief track engineer (CTE) in open lines and the chief administration officer (construction) (CAO/C) for construction projects. Relaxation in abrasion and impact values is given prior to the invitation of tender and should be incorporated in the tender document.

8.6.3 Size and Gradation

The ballast should satisfy the size and gradation requirements given in Table 8.5.

Table 8.5 Ballast gradation

Size of sieve	*% retained*
65 mm	5% maximum
40 mm	40% to 60%
20 mm	Not less than 98% for machine crushed and not less than 95% for hand broken

8.6.4 Oversized Ballast

(a) *Retention on 65-mm square mesh sieve* A maximum of 5% ballast retained on a 65-mm sieve is allowed without deduction in payment. In case the ballast retained on a 65-mm sieve exceeds 5% but is less than 10%, payment at a 5% reduction of 5% in the contracted rate is made for the full stack. Stacks retaining more than 10% of ballast on a 65-mm sieve are rejected.

(b) *Retention on 40-mm square mesh sieve* In case the ballast retained on a 40-mm square mesh sieve (machine crushed only) exceeds the 60% limit prescribed above, payment at the following reduced rates is made for the full stack in addition to the reduction as worked out above.

   (i) 5% reduction in contracted rates if the retention on a 40-mm square mesh sieve is between 60% (excluding) and 65% (including).

   (ii) 10% reduction in contracted rates if retention on a 40-mm square mesh sieve is between 65% (excluding) and 70% (including).

   (iii) In case the retention on a 40-mm square mesh sieve exceeds 70%, the stack is rejected.

   (iv) In the case of hand broken ballast supply, 40-mm-sieve analysis may not be carried out. The executive may, however, ensure that the ballast is well graded between 65 mm and 20 mm.

8.6.5 Undersized Ballast

The ballast is treated as undersized and rejected if

(a) retention on a 40-mm sieve is less than 40% and

(b) retention on a 20-mm sieve is less than 98% (for machine crushed ballast) or 95% (for hand broken ballast).

8.6.6 Shrinkage Allowance

Payment is made for the gross measurements either in stacks or in wagons without any deduction for shrinkage/voids. However, when ballast is supplied in wagons, up to 8% shrinkage is permitted at the destination by the consignee verifying the booked quantities.

8.6.7 Sampling and Testing

The following procedure is specified for the sampling and testing of the ballast.

(a) A minimum of three samples of ballast should be taken for sieve analysis for measurement done on any particular date, even if the number of stacks to be measured is less than three.

(b) The tests for abrasion value, impact value, and water absorption should be done in approved laboratories or in the Railways' own laboratories (A list of these laboratories should be given in the tender document).

(c) In order to ensure the supply of a uniform quality of ballast, the specifications given in Table 8.6 should be followed with respect to sampling, testing, and acceptance of the ballast. The tests given in this table may be carried out more frequently if warranted at the discretion of the Railways.

(d) On supply of the first 100 m^3, tests for size gradation, abrasion value, impact value, and water absorption (if prescribed) should be carried out by the Railways. Further supply should be accepted only after the first batch satisfies these tests. The Railways reserves the right to terminate the contract as per the general conditions of contract (GCC) at this stage itself in case the ballast supply fails to meet any of these specifications.

Table 8.6 Frequency of tests for ballast supply

Item	*Supply in stacks*		*Supply in wagons*
	For a stack of volumne less than 100 m^3	*For a stack of volume more than 100 m^3*	
Number of size and gradation tests	One for each stack	One for each stack	One for each wagon
Size of one sample* (m^3)	0.027	0.027 for every 100 m^3 or part thereof	0.027
Abrasion value, impact value, and water absorption test†	One test for every 2000 m^3 of ballast		

* This sample should be collected using a wooden box of internal dimensions 0.3 m × 0.3 m × 0.3 m from different parts of the stack/wagon.

† These tests should be done for the purpose of monitoring the quality during supply. In case the test results are not as per the prescribed specifications at any stage, further supplies should be suspended till suitable corrective action is taken and supply as per specifications is ensured.

8.7 Collection and Transportation of Ballasts

The collection and transportation of ballasts can be done by either of the following methods.

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

The mode of collection is decided taking into account the proximity of the quarry, availability of good stone ballast, serving roads along side the railway line for the carriage of ballast, availability of ballast trains, turnround of ballast trains, and availability of traffic blocks for unloading.

8.7.1 Collection at Ballast Depots

The following procedure is adopted when ballasts are being collected at ballast depots.

(a) The space along side the railway line meant for stacking is divided into a convenient number of zones and demarcated.

(b) For each depot, a diagram indicating the site details of all the measured stacks is maintained.

(c) Each stack in each zone is serially numbered.
(d) Operations of collecting and training out materials should not be carried out at the same time in any zone.
(e) The ground on which the stacks are made should be selected and levelled.
(f) Measurements should be taken for complete stacks. The measured stack should be identified suitably by lime sprinkling or any other method.
(g) As soon as a stack is lifted, it should be recorded on the depot diagram, which should always be kept up-to-date. Challans should be prepared after loading the ballast into wagons.

8.7.2 Collection of Ballast Along the Cess

In case the ballast is collected along the side of the cess, the inspector in charge should maintain a separate register showing the measurement of stacks as well as its disposition (from km to km). The stacks should be serially numbered between successive posts. Entries should be made in a register whenever stacks are removed and ballast is put onto the track. The record should state the place where the removed ballast has been used as well as the date of removal of the stack. Materials passing through a 6-mm square mesh are classified as ‘dust’ (limited to 1%).

8.8 Methods of Measurement

The quantity of the ballast can be measured either in a stack or in a wagon. Both methods are described below.

8.8.1 Stack Measurement

Stacking should be done on an almost plane and firm ground with good drainage. The height of the stack should not be less than 1 m except in hilly areas, where it may be 0.5 m. The top width of the stack should not be less than 1 m and should be kept parallel to the ground plane. The side slopes of the stack should not be flatter than 1.5:1 (horizontal:vertical). The volume of each stack should normally not be less than 30 m^3 in plain areas and 15 m^3 in hilly areas.

8.8.2 Wagon Measurement

In the case of the ballast supply being directly loaded into wagons, a continuous white line should be painted inside the wagon to indicate the level up to which the ballast can be loaded. The volume in cubic metres corresponding to white line should also be painted outside the wagon on both sides. In addition to the painted line mentioned above, short pieces of flats (cut pieces of tie bars or otherwise) punched with the volume should be welded in the centre of all the four sides of the wagon.

8.9 Laboratory Tests for Physical Properties of Ballast

The following tests are recommended to judge the suitability of the ballast material for a railway track.

8.9.1 Aggregate Abrasion Value

To check for aggregate abrasion, a test sample of 10 kg of clean ballast conforming to the following grading is taken

Passing the 50-mm sieve and retained on the 40-mm square mesh sieve: 5000 g
Passing the 40-mm and retained on the 25-mm square mesh sieve: 5000 g

The sample, along with the abrasive charge, is placed in the Los Angeles machine, which is rotated at a speed of 30–33 rpm for 1000 revolutions. The sample is sieved and material coarser than the 1.70-mm sieve is washed, dried, and weighed. The difference between the original weight (*A*) and the final weight of the sample (*B*) is expressed as a percentage of the original weight of the test sample. This value is reported as the abrasion value.

$$\text{Aggregate abrasion value} = \frac{A - B}{A} \times 100 \tag{8.2}$$

8.9.2 Aggregate Impact Value

To check for aggregate impact, the test sample is prepared out of the track ballast in such a way that it has a grading that passes the 12.5-mm sieve and is retained on the 10-mm sieve. The ballast sample is oven dried and placed duly tamped in the different stages in a cylindrical metal container with 75 mm diameter. and 50 mm depth (weight *A*). The cup of the impact testing machine is fixed firmly in position on the base of the machine and entire test sample is placed in it and compacted by 25 strokes of the tamping rod. The test hammer weighing about 14 kg is raised 380 mm above the upper surface of the cup and dropped. The test sample is subjected to a total of 15 such blows. The sample is then removed and sieved using a 2.36-mm sieve and the weight of quantity retained is measured (weight *B*):

$$\text{Aggregate impact value} = \frac{A - B}{A} \times 100 \tag{8.3}$$

8.9.3 Flakiness Index

The flakiness index of an aggregate is the percentage by weight of the particles with a least dimension (thickness) less than three-fifths of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.

Track ballast sample of sufficient quantity is taken to provide a minimum of 200 pieces, which is weighed (weight *A*). The sample consisting of aggregates is sieved as per the prescribed procedure in a series of sieves. The flaky material is separated and weighed (weight *B*). The flakiness index is then determined by the total weight of the material passing the various sieves, expressed as a percentage of the total weight of the sample gauged.

$$\text{Flakiness index} = \frac{B}{A} \times 100 \tag{8.4}$$

8.9.4 Specific Gravity and Water Absorption Test

A sample consisting of at least 2000 g of aggregate is washed thoroughly to remove finer particles and dust. The whole material is then drained, placed in a wire basket, and immersed in distilled water at a temperature between 22°C and 32°C. The sample is shaken, jolted, and dried as per specific procedure. The sample is finally placed in an oven in a shallow tray at a temperature of 100°C to 110°C. It is then removed from the oven, cooled in the container, and weighed (weight *C*). The specific gravity and water absorption is calculated as follows:

$$\text{Specific gravity} = \frac{C}{B - A} \tag{8.5}$$

$$\text{Water absorption (\% by weight)} = \frac{100\,(B - C)}{C} \tag{8.6}$$

where A = weight in grams of saturated aggregate in water, B = weight in grams of saturated dry aggregate in air, and C = weight in grams of oven-dried aggregate in air.

8.10 Assessment of Ballast Requirements

The requirements of the ballast should be assessed separately for

(a) correcting the deficiencies existing in the track as well as those arising out of overhauling, through packing and deep screening,
(b) providing adequate cushion for mechanical tamping, and
(c) providing extra cushion while converting into LWR.

The ballast required for maintenance purposes is estimated by assessing the quantity approximately, if necessary by a survey, over every 1 km of rail length. Care should be taken to ensure that the cores under the sleepers are not disturbed.

In the case of deep screening, the ballast required for recoupment and providing a standard section should be assessed by deep screening the ballast on a trial basis. For this, full depth screening is done for a length of 2–3 sleepers at every 0.5 to 1 km interval. In this case, the screening is done under the sleepers as well. The quantity of ballast required for deep screening is roughly taken as 1.5% of the existing quantity of ballast based on field trials.

The quantities assessed above will be the net quantities of ballast required to recoup the deficiencies or to provide required profiles/sections. These net quantities of ballast may be enhanced suitably (say by 8%) to arrive at the gross quantities of ballast needed for the purpose of procurement in case the measurements are proposed to be taken in stacks or wagons at the originating station.

8.11 Guidelines for Provision of Sub-ballast

The sub-ballast is normally made of granular material and is provided between the formation and the ballast in order to distribute the load evenly over the formation. The following points should be kept in mind while selecting a material for sub-ballasts.

(a) The material should consist of coarse granular substance such as river gravel, stone chips, quarry grit, and predominantly coarse sand. Ash, cinder, and slag containing predominantly fine and medium sand should not be used.
(b) The material should be non-cohesive and graded. The uniformity coefficient should be more than 4 to ensure that the sub-ballast is well graded.
(c) The material should not contain more than 15% of fines that measure less than 75 microns.
(d) The thickness of the sub-ballast should not be less than 150 mm.

Summary

The ballast is a layer of granular material provided below and around sleepers to distribute load from the sleepers over a larger area of the formation. Any granular material can be used as ballast if it satisfies certain requirements of strength, size, and gradation. The ballast gets crushed because of the dynamic action of the wheel load and, therefore, requires regular maintenance. The thickness of the ballast cushion under the sleepers depends upon the axle load, type of sleepers, sleeper density, and other related factors.

Review Questions

1. Mention the properties required of a good ballast for a railway track.
2. Explain briefly how the pressure created by wheel loads is transmitted through the ballast. What factors of the ballast influence the intensity of the pressure on the formation?
3. (a) What are the functions of the ballast in a railway track?
   (b) Explain the elastic-cum-frictional behaviour of ballast under passing wheel loads.
   (c) What types and sizes of ballast are required for measured shovel packing?
4. What is the ballast? Why is it used in the railway track? Briefly describe the various types of ballasts used.
5. Explain the following with respect to the ballast used on Indian Railways.
   (i) Functions
   (ii) Requirements of ideal ballast material
   (iii) Different materials used for ballast and their relative merits
6. Name six materials commonly used as ballast on Indian Railways. Write down the specifications of an ideal stone ballast.
7. Determine the optimum thickness of the stone ballast required below sleepers of density $M + 7$ on a BG track. (***Ans***: 19.8 cm)
8. Sketch a typical section of an MG line on wooden sleepers and show the ballast cushion and side slopes for a sleeper density of $M + 3$.
9. What size of ballast is used for the main line, and points and crossings on Indian Railways?
10. Write short notes on the following.
    (a) Abrasion test

(b) Impact test
(c) Oversized ballast
(d) Sub-ballast

Week-(17)

MD Ehasan Kabir

CHAPTER
26

Railway Stations and Yards

Introduction

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. However, most railway stations perform both the functions indicated above.

26.1 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

26.2 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.

26.3 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.

26.4 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.

26.5 Classification of Railway Stations

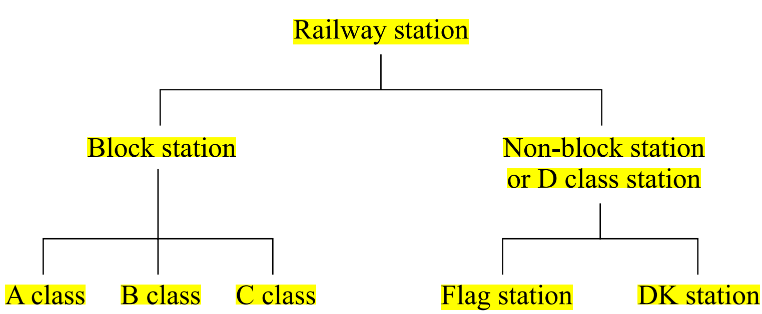
Railway stations can broadly be sorted into various classes on the basis of two main considerations.

Operational considerations

As per the general and subsidiary rules of Indian Railways stations are classified as block stations and non-block stations. Block stations are further classified as A class, B class, and C class stations. Non-block stations are classified as D class or flag stations.

Functional considerations

Stations are classified based on the functions they are required to perform. Under this category, stations are classified as halt stations, flag stations, crossing stations or wayside stations, junction stations, and terminal stations.



The following factors are taken into consideration when classifying a railway station.

(a) Least expenditure with regard to the provision of the least number of signals
(b) Flexibility in shunting operations
(c) Increasing the line capacity
(d) Faster movement of trains

26.5.1 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.

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. The typical layout of an A class station with two-aspect signalling is shown in Fig. 26.1.

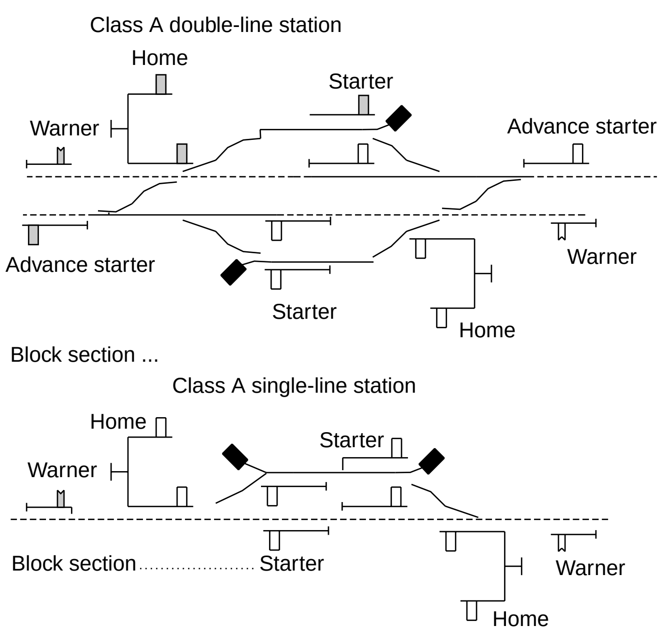


Fig. 26.1 A class station

The signals required at an A class station are as follows.

Warner A warner signal is placed at a warning distance from the home signal, the main function of which is to indicate whether the section beyond is clear or otherwise.

Home A home signal, which is the first stop signal.

Starter A starter signal is placed at an adequate distance from the home signal and marks the point up to which the line should be clear so that the train can be given permission to approach.

Advance starter This signal is optional and is provided to allow the drivers to further increase the speed of the trains.

Advantages

(a) More economical vis-à-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.

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 (Fig. 26.2), the line has to be clear up to an adequate distance beyond the outer signal before 'permission to approach' can be given to a train. The minimum signals required at a B class station are as follows.

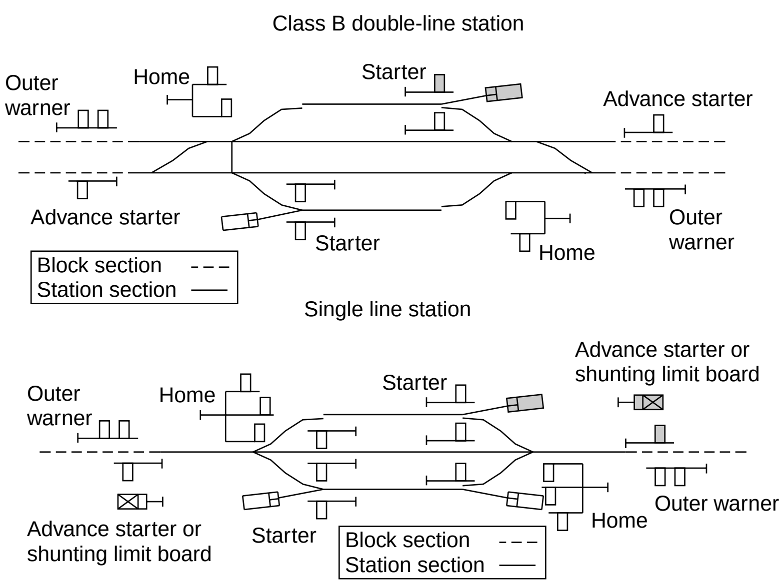


Fig. 26.2 B class station

Outer An outer signal, which is the first stop signal. The outer signal can also be below the warner also.

Home A home signal, which protects the facing point and is placed at an adequate distance from the outer signal.

Starter A starter signal is also provided on a double-line section.

The B class station is the most common station in use on Indian Railways because it offers greater flexibility of working. By providing a warner on the outer arm post, this station can also cater to fast traffic while permitting shunting of vehicles even when a clear signal has been given.

C class station

The C class station (Fig. 26.3) 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. The minimum signals required are as follows.

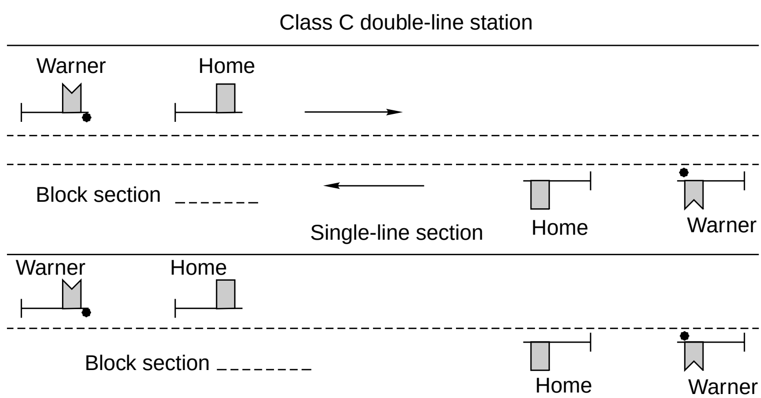


Fig. 26.3 C class station

Warner A warner signal placed at an adequate warning distance from the home signal to indicate whether the section ahead is clear or not.

Home A home signal, which is the first stop signal.

The advantage of a C class station is that it ensures the faster movement of trains and increases line capacity. The disadvantage, however, is that no shunting is possible and trains cannot stop at these stations.

26.5.2 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*.

26.5.3 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

Halt

A halt (Fig. 26.4) 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.

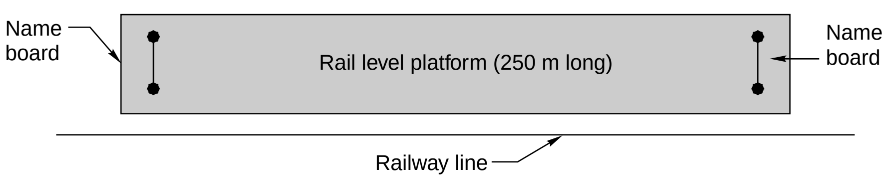


Fig. 26.4 Layout of a halt station

Flag station

A flag station (Fig. 26.5) 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.

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.

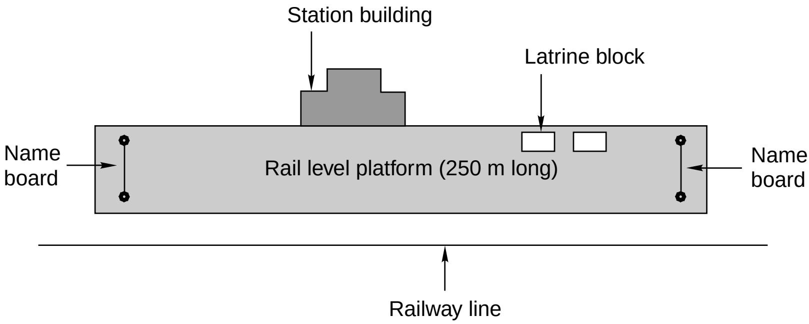


Fig. 26.5 Layout of a flag station

Crossing stations may be further classified as (a) Roadside small- and medium-sized stations and (b) Major stations. Some of the important tasks dealt with these stations are the following.

Operating work The main operations performed at these stations include attending to the passing and crossing of trains, giving precedence to important trains, and other miscellaneous works done for stopping passenger trains. Slow passenger trains mostly stop at small stations whereas mail and express trains stop at major stations.

Goods traffic These stations mostly deal with parcel traffic only. Piecemeal wagon load goods traffic is now being accepted on roadside stations as per the new policy of the Railway Ministry with effect from December 1994.

Operation of points and signals The operation of points and signals is controlled either by a central cabin or two cabins at either end of the station.

Reception and dispatch of trains The reception and dispatch as well as shunting of trains is handled as per the instructions laid down in the 'station working order'. Block instruments are provided either in the station master's office or in the cabin, but the entire responsibility of carrying out these operations lies with the station master.

Station master's duty for run-through trains When a train runs through the station, the station master should stand opposite his office in proper uniform and exchange 'all right' signals with the driver and guard of the train. He should watch the running train carefully and if there are any unusual occurrences such as the incidence of a hot box, he should instruct the station officials in advance to stop and examine the train.

Wayside or crossing station on a single-line section Increasing traffic on a single-line section necessitates the construction of a three-line station, which provides an additional line as well as more facilities for passing traffic. A typical layout of a three line station providing one additional line and simultaneous reception facilities is given in Fig. 26.6. It may be possible to improve the facilities further by introducing an additional line to deal with goods traffic.

The following are some of the important features of this track layout.

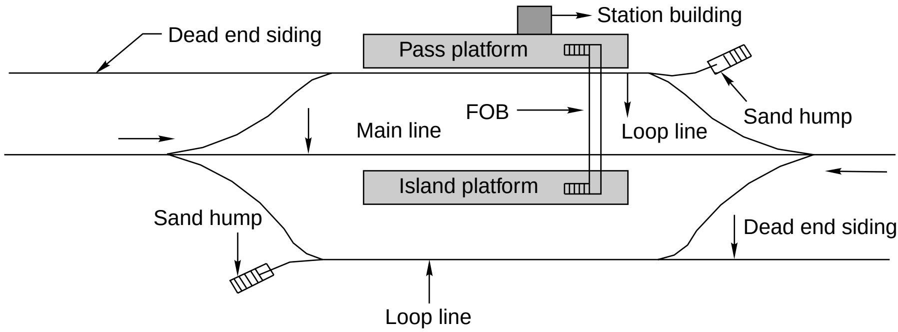


Fig. 26.6 A wayside or crossing station on a single-line section

(a) It is a three-line station and provides facilities for the simultaneous reception of trains from both sides because of the proximity of sand humps in each direction.

(b) There are two platforms, namely, an island platform and a platform near the station building. The island platform can deal with two stopping trains simultaneously. Also, if a goods train has to be stopped at an island station, it can be accommodated on the loop line of the platform, thus keeping the main line free for run-through traffic. Important trains can be made to halt on the platform near the station building.

(c) There is a dead end siding at either end of the station to accommodate wagons that are marked sick.

(d) The foot over bridge (FOB) helps the passengers to reach the island platform from the station building and vice versa.

Double-line crossing station with an extra loop In the case of a double-line section, which consists of separate up and down lines to deal with traffic moving in either direction, the layout of a station yard is somewhat different.

Figure 26.7 shows a double-line station with three lines receiving, with one common loop for trains coming from both sides. Some of the important features of this layout are as follows.

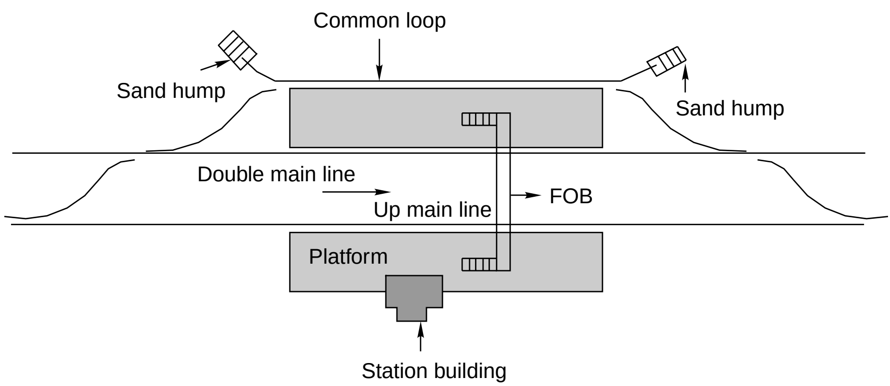


Fig. 26.7 Double-line crossing station with three lines

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

Double-line crossing station with four lines The more common layout of a station yard on a double-line section has four lines station as shown in Fig. 26.8. The important features of this layout are as follows.

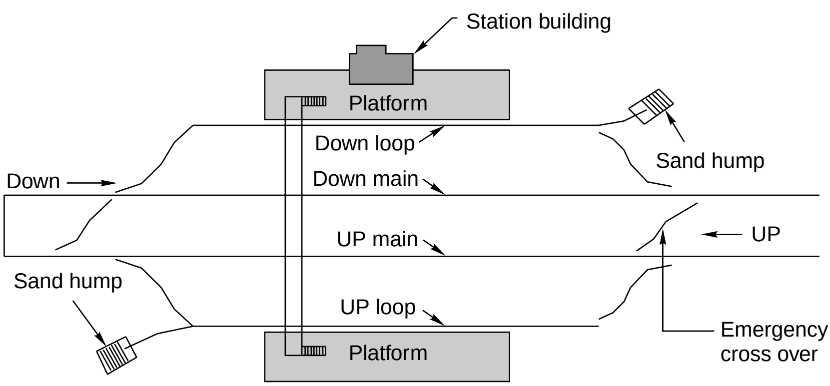


Fig. 26.8 Double-line crossing station with four lines

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

Junction 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.

The typical layout of a junction station with a single main line and a single branch line is shown in Fig. 26.9. The important features of junction stations are as follows.

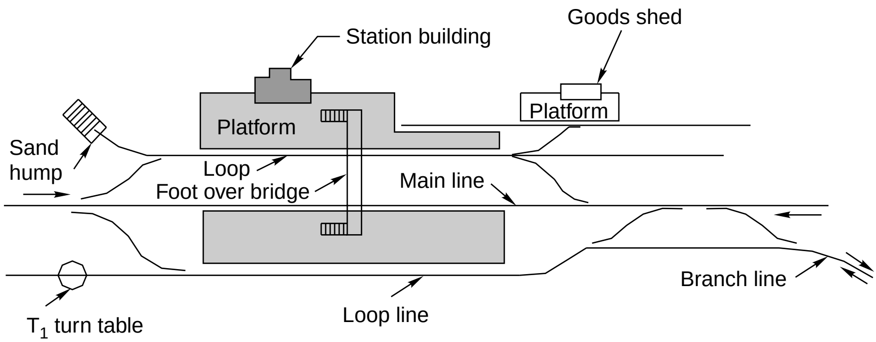


Fig. 26.9 Junction station with single main line and single branch line

(a) There are two platforms—one is the main line platform and the other is an island platform. In case the timings of two trains match, both the trains can be received and made to wait on either side of the island platform. This helps in the easy trans-shipment of passengers and luggage. Also, main line as well as branch line trains can be received on the main platform.

(b) A foot over bridge is provided for passengers to move between the station platform and the island platform.

(c) It is provided with a small goods siding and a goods platform to deal with goods traffic.

(d) A turntable is provided for reversing the direction of an engine, if required.

(e) The emergency crossover on provided either side of the station helps in switching to a single-line set-up in the case of an emergency.

A few examples of junction stations are the Ghaziabad, Allahabad, Itarsi, Nagpur, and Jabalpur junctions. The typical layout of a junction station on a double-line section with one or two branch lines coming in from one or two different directions is shown in Fig. 26.10. The most important feature of this layout is that such a station receives traffic from four different directions, i.e., up main line, down main

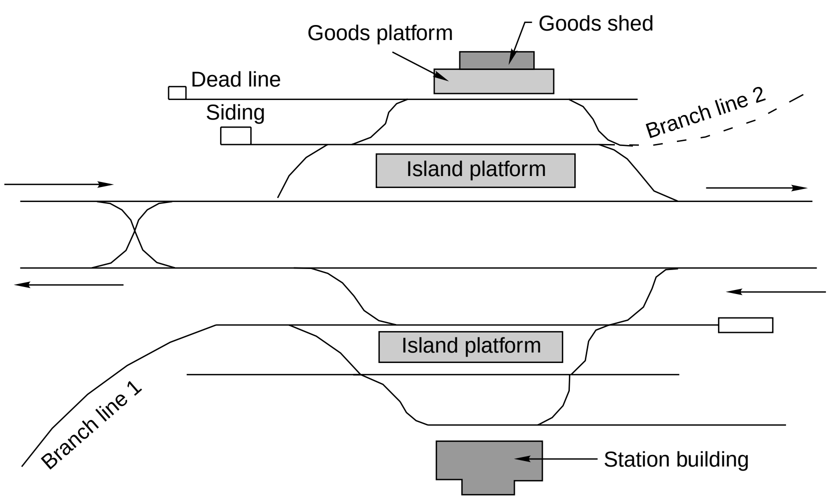


Fig. 26.10 Junction station with double main line and two branch lines

line, branch line 1, and branch line 2. Most of the facilities provided at this station are almost the same as described for the layout shown in Fig. 26.9.

Terminal station

The station at which a railway line or one of its branches terminates is known as a terminal station or a terminal junction (Fig. 26.11). The reception line terminates in a dead end and there is provision for the engine of an incoming train to turn around and move from the front to the rear of the train at such a station. In addition, a terminal station may need to be equipped with facilities for watering, cleaning, coaling, fuelling, and stabling the engines; storing, inspecting, washing and charging the carriages; and such other works.

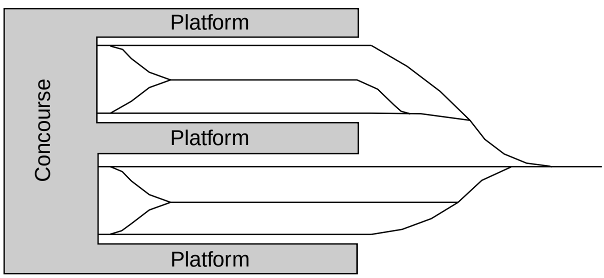


Fig. 26.11 Terminal station with run round line

On unimportant branch lines, the terminal station will have only one platform, but there are big terminal stations such as the Howrah and Mumbai stations, which are provided with elaborate facilities. The general layout of a big terminal station is shown in Fig. 26.12.

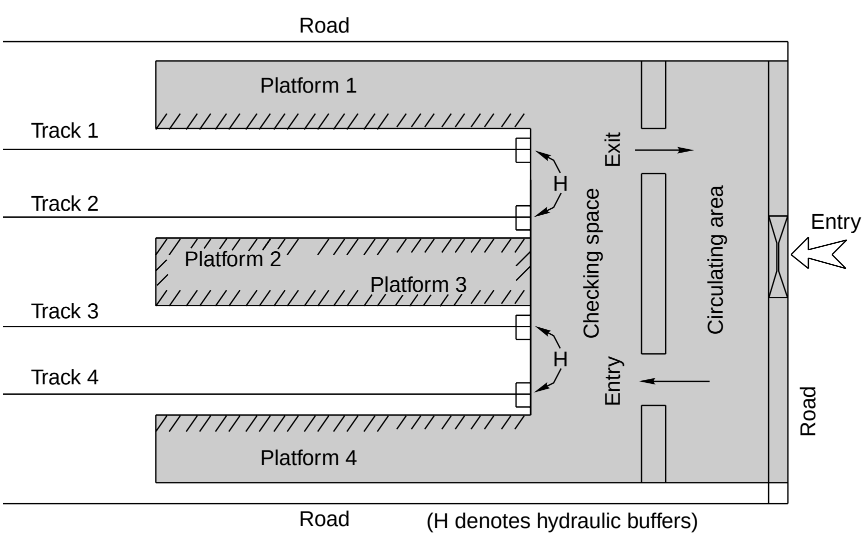


Fig. 26.12 Layout of a big terminal station

It may be noticed that access from one platform to another is via a concourse and that there are no overbridges provided for this purpose.

Grand Central Station at New York Figure 26.13 depicts the circular loop provided at the Grand Central Station, New York. The provision of circular loops enables the trains to pass through a terminal station without any delay. A further advantage attached to the loop system is that it enables the provision of special stations for dealing with suburban traffic at underground locations away from the congested area of the main terminal and in close proximity to business districts, thus affording direct connections with other stations.

26.6 Station Platforms

Station platforms are provided for the entraining and detraining of passengers. Platforms can be rail-level, low-level, or high-level platforms depending upon the expected passenger traffic at each station. The general policy of Indian Railways is to provide high-level platforms at all important main line stations, low-level platforms at less important main line stations, and rail-level platforms at unimportant wayside stations.

The height of rail level platforms coincides with the rail level, low-level platforms lie at a height of 455 mm (1′–6″), and high-level platforms lie at a height of 760 mm to 840 mm (2′–6″ to 2′–9″) in the case of BG lines and 305 mm to 405 mm (1′–0″ to 1′–4″) in the case of MG lines. Other details of these platforms are given in Table 26.1.

Table 26.1 Important features of passenger and goods platforms

Item	*Details*	
Passenger platforms		
Height of platform	High-level platforms (for all important main line stations)	0.76–0.84 m on BG, 0.305–0.405 m on MG
	Low-level platforms (less important than these for main line stations)	0.455 m on BG
	Rail-level platforms (for unimportant wayside stations)	At rail level
Length of platform	Enough length to accommodate the longest passenger train on the station. Minimum length of platform to be 180 m. Normally, a platform of a length of 450 m is provided on a main line to accommodate 20 bogies.	
Width of platform	Platform to be wide enough to accommodate the entire train load of passengers. The suggested yardstick for the width of a platform is 1.5 m^2 per passenger for main line and 1.0 m^2 per passenger for suburban trains. Minimum width of platform to be 3.66 m.	
End of platform	A ramp is provided with a slope of 1 in 6.	

(*contd*)

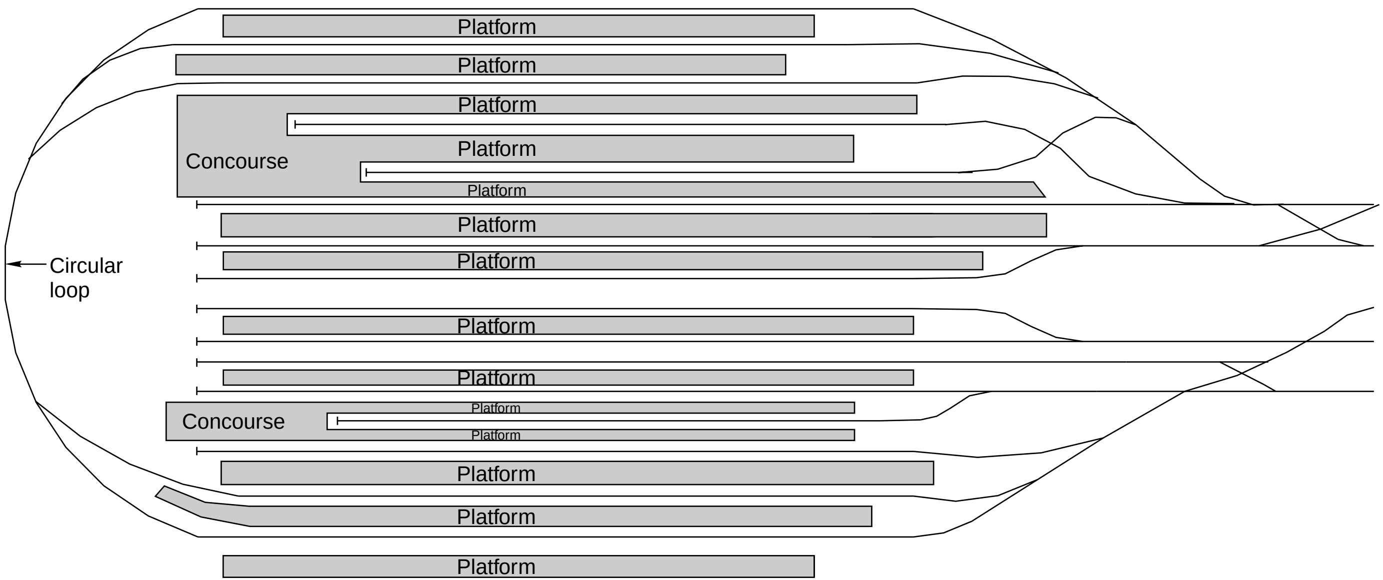


Fig. 26.13 Circular loop at Grand Central Station, New York

Table 26.1 (*contd*)

Item	*Details*
Platform cover	Platform to be covered as per passenger requirement. Minimum length of platform cover to be 60 m.
Water supply	The number of taps approved is two taps per 100 passengers.
Toilets, urinals, and bathrooms	The prescribed scale is four toilet seats per 100 passengers, one urinal per 100 passengers, and one bathroom per 200 passengers.
Station name boards	Two station name boards to be placed, one on each side of the platform, perpendicular to the track. Name of the station to be written in Hindi, English, and the regional language. Height of underside of boards to be 1.8 m.
Goods platforms	
Height of platform	BG 1.07 m, MG 0.69 m, and NG 0.61 m
Length of platform	Adequate enough to deal with goods received or dispatched; normally not less than 60 m.
Width of platform	Depends upon volume of traffic, minimum width specified is 3.1 m.
Other facilities	Weighing facilities, direct access road, paved platform, etc.

26.7 Main Building Areas for Different Types of Stations

The main facilities provided in the case of a small station are a waiting hall, booking hall, assistant station master's (ASM) office, and storeroom. Different designs have been standardized for each type of station by the various railways, which provide all the facilities required by small and medium-sized stations. When considering big stations, however, the design of an individual station building has to be drafted based on the requirement of passenger traffic with due regard to its architectural features.

Central Railways has prepared a type drawing for wayside stations, which provides different facilities for different types of station buildings as summarized in Table 26.2.

Table 26.2 Facilities at different types of stations

Type of station	*Plinth area (m^2)*	*Scale of facilities*
Type A	118.6	Waiting hall, booking and ASM office, and storeroom
Type B	159.3	Waiting hall, booking and ASM office, parcel office, and storeroom.
Type C	269.4	Waiting hall, booking and ASM/SM office, parcel office, inspection room, and storeroom.
Type D	406.0	II class waiting hall, upper class waiting hall, booking office, ASM/SM office, storeroom, parcel office, inspector's waiting room

26.8 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.

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.

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.

Marshalling yard

A goods yard which deals with the sorting of goods wagons to form new goods trains is called a marshalling yard. This is discussed in detail in Section 26.8.1.

Locomotive yard

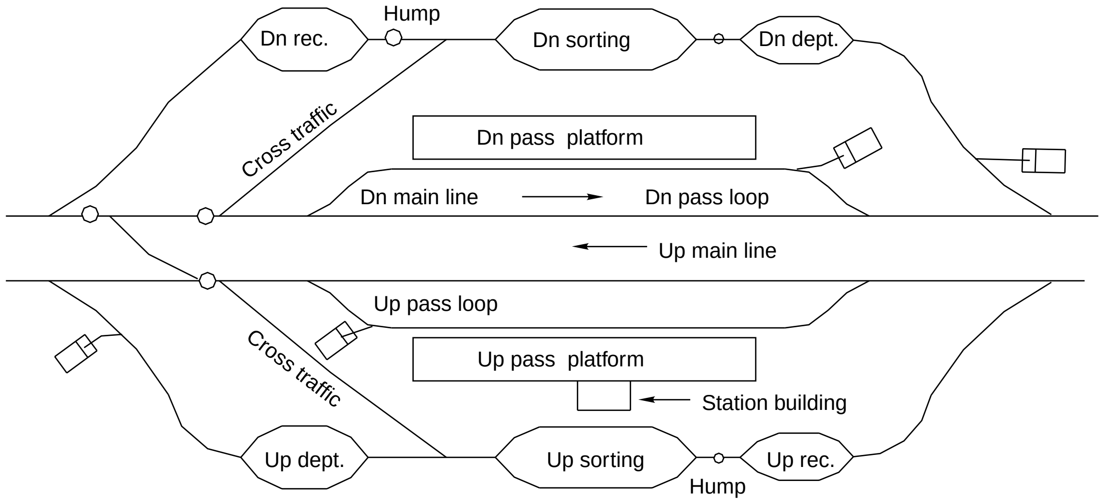
This is the yard which houses the locomotive. Facilities for watering, fuelling, examining locomotives, repairing, etc., are provided in this yard. The yard layout is designed depending upon the number of locomotives required to be housed in the locomotive shed. The facilities are so arranged that a 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.

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.

26.8.1 Marshalling Yard

The marshalling yard (Fig. 26.14) is a yard where goods trains are received and sorted out, and new trains are formed and finally dispatched to various destinations.



Marshalling yard with separate humps and separate sorting lines

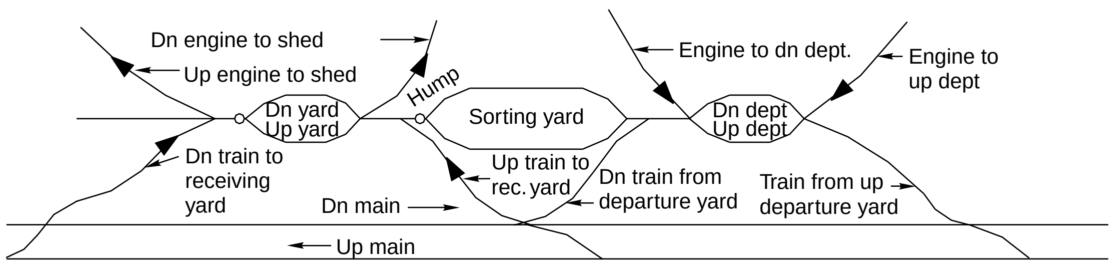


Fig. 26.14 Marshalling yard with a common hump and common sorting yard

This yard receives loaded as well as empty goods wagons from different stations for further booking to different destinations. These wagons are separated, sorted out, properly 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 en route at wayside stations.

Functions

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

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

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

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

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.

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.

Flat yard In this type of yard, all the tracks are laid almost level and the wagons are relocated for sorting, etc., with the help of an engine. This method is costly, as it involves frequent shunting, which requires the constant use of locomotive power. The time required is also more as the engine has to traverse the same distance twice, first to carry the wagons to the place where they are to be sorted and then to return idle to the yard. This arrangement, therefore, is adopted when

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

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

Hump yard In this yard, an artificial hump is created by means of proper earthwork. The wagons are pushed up to the summit of the hump with the help of an engine from where they slide down and reach the sidings under the effect of gravity. A hump yard, therefore, can be said to be a gravitation yard as shunting is done under the effect of gravity. The gradients normally adopted in this regard are listed in Table 26.3. 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.

Table 26.3 Gradients in marshalling yards

Item	*Gradients to be adopted for*	
	Mechanical yards	*Non-mechanical yards*
Rising gradient of approach	1 in 50 to 1 in 125	1 in 50 to 1 in 100
Top of hump	Level	Level
First falling grade after apex of hump	1 in 17 to 1 in 20	1 in 25 to 1 in 35
Intermediate grade up to the point where the trains start	1 in 50 to 1 in 60	1 in 80 to 1 in 200
Final falling gradient up to clearance of points	1 in 200 to level	1 in 80 to 1 in 200
Gradient of the sidings	Down-gradient eased off and then an up-gradient given to stop wagons at the end	Falling gradient 1 in 400 to 1 in 600

Regulation of speeds in hump yards The speed of the wagons is regulated to ensure that they are kept in a stable condition in the siding where they are to be sorted, so that there is least damage to them. The regulation of speed is done as follows.

Mechanical method In this method, wagons are slowed down automatically with the help of 'retarders' (Fig. 26.15). Retarders' normally in the shape of bars fixed on either side of the track, operate electrically or electromechanically and offer resistance to the movement of wagons by pressing against the sides of the moving wheels. This finally stops the wagons at the appropriate place. Such mechanical retarders are used extensively in Germany and on other developed railways.

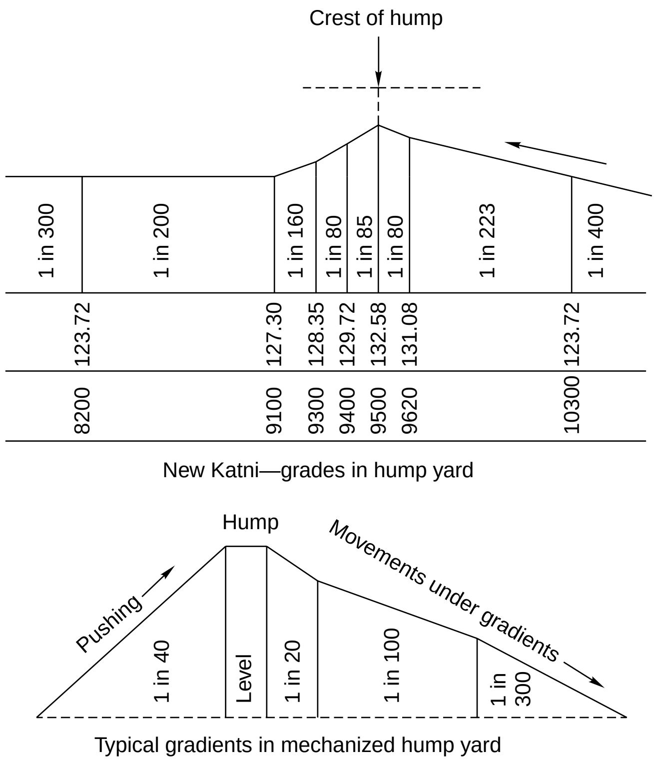


Fig. 26.15 Gradients in mechanical hump yard

Non-mechanical yard In a non-mechanical yard, the speed of the wagon is regulated manually with the help of hand brakes or skids. A shunting porter runs alongside the wagons and applies a hand brake to the wagon at an appropriate place, making the wagon slip and stop. Skids are also used to slow down the wagons. Skids are placed on the track; they get dragged by the rolling wagon and the friction thus developed reduces the speed of the wagon and stops it at the desired location.

Design of various constituents

The design details of the various components of a marshalling yard are discussed below.

Spacing of marshalling yards This depends upon the average distance that a long-distance train can go. If the lead is 500 km and the section train can go up to 100 km, the approved spacing of a marshalling yard is 400 km.

Siting of marshalling yard A marshalling yard is normally sited at a junction point, a depot yard to a group of collieries, a feeder yard for a big terminal point, or a steel plant, etc.

Reception yard The number of lines to be included in a reception yard depends upon the number of trains to be received and on the frequency of their arrival. Normally one reception line is provided for every three to four trains. The approved length of a siding is normally 700 m for BG and 650 m for MG.

Shunting neck The length of the shunting neck should be longer than the longest train.

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. The figures given in Table 26.4 can be taken as a rough guide for choosing the design of the humps.

Table 26.4 Design of humps

Design element	*Suggested value*
Average gradient from the hump to the end of switching zone	2% for empty and 1.5% for loaded wagons
Average height of ordinary hump	2.5–3 m (8–10 ft)
Average height of mechanized hump	3.5–6 m (12–20 ft)

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.

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.

The pattern of transportation of goods traffic has changed drastically in the recent past. Now, most goods traffic is carried as trainloads from point to point. The loading of piecemeal wagons has also been drastically reduced. Consequently, the need and importance of goods marshalling yards has reduced considerably.

26.9 Catch Sidings and Slip Sidings

Catch sidings are provided in the case of hilly terrains, where the gradients near railway stations are very steep. The purpose of catch sidings is to arrest the movement of the vehicles if they start to roll down the grade, which may eventually foul up the running lines. A separate siding is provided outside the station yard so that the vehicles can be collected there.

In Fig. 26.16, DEF is a running line and AB is a dead end siding. BC is the catch siding connected to the dead end siding preferably by the means of a spring-operated point. The catch siding lies on a rising gradient and its length is so designed that the vehicle loses its kinetic energy when it reaches the dead end. Thus the vehicle is protected from damage and the safety of the trains on the running line is ensured. There is a sand hump provided at the end of the catch siding to prevent any minor damage to the vehicle.

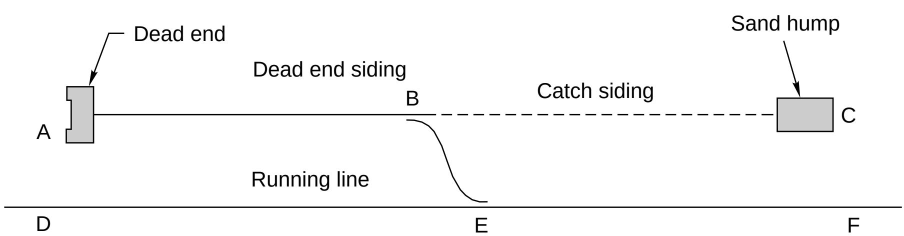


Fig. 26.16 Catch siding

In the case of hilly terrains, normally one siding is provided at each end of the station as explained here.

Catch sidings These are provided at the higher level or upper end of a station when it starts to slope downwards along the track in an unauthorized manner from the previous station.

Slip sidings These are provided at the lower level on the lower end of the station. If by chance the vehicle is not caught in a catch siding and enters the station premises, the same will be caught and shipped into the slip siding.

Clapham Junction (London) of the Southern Region on British Railways is probably the greatest junction station in the world. It has 17 platforms but 12 of these lines are used by trains that either make only an ordinary station stop or do not stop at all. The other five platforms are used for miscellaneous purposes and are chiefly provided for trains transporting milk and other similar articles, which require a significant stop before the lines can be cleared. Thus, as many as 2500 trains can run daily with ease from this station, as very few trains occupy the platform for more than a minute or so.

Summary

Stations and yards are provided to control the movement of trains, passengers, and goods. Stations are classified based on their operational and functional characteristics. The facilities to be provided at a station depend upon the type of station it is. Similarly, yards are also classified as coach yards, goods yards, marshalling yards, or locomotive yards depending upon their purpose. The efficiency of a station largely depends on the efficiency of its yards.

Review Questions

1. (a) What are marshalling yards and where are they usually located?
   (b) Enumerate the principal types of marshalling yards and the basic facilities that should be provided with each one of them.
   (c) Approximately estimate the yard capacity of a marshalling yard that is required to deal with 1000 wagons a day with an average detention of wagons of 18 hours during the peak season. To ensure proper fluidity, assume a suitable yard balance.
2. (a) Name the different types of marshalling yards. With the help of a neat sketch explain how goods train arriving at such a yard from different directions could be rearranged into their proper order.
   (b) Explain the following.
   (a) Flag station and block station
   (b) Island platform and dock platform
   (c) Junction and terminal
3. What is the purpose of providing marshalling yards? What are the points to be considered in the design of marshalling yards? What are the main siding features of marshalling yards?
4. What are the functions of a railway station? Explain briefly the various requirements of a railway station at an important city.
5. Draw a diagrammatic and dimensioned layout of a BG three liner crossing station with the minimum provisions for goods handling. Also mark the signals at either end at the appropriate distances. Assume the station to be a B class station with standard III interlocking and 70 wagons loop capacity.

CHAPTER
31

Signalling and Interlocking

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.

31.1 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.

31.2 Classification of Signals

Railway signals can be classified based on different characteristics as presented in Table 31.1.

Table 31.1 Classification of signals

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

Figure 31.1 shows the further classification of audible and visible signals. Table 31.2 lists the minimum signal requirements of various classes of stations.

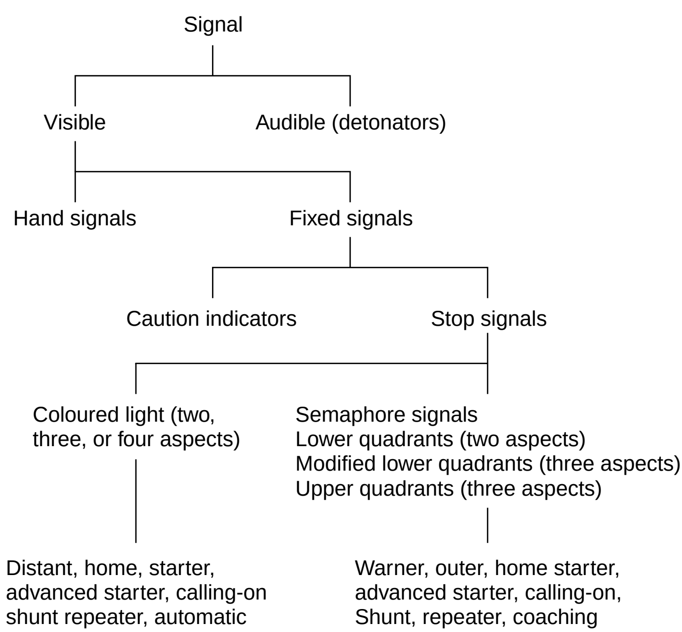


Fig. 31.1 Classification of signals

Table 31.2 Signals required at stations

Classification of station	*Minimum requirement of signals*	*Remarks*
A class	Warner, home, and starter	An outer signal can be provided after obtaining special permission
B class	Outer and home	In multiple-aspect upper quadrant (MAUQ) areas, distant home and outer signals are provided
C class	Warner and home	In MAUQ areas, the warner signal is replaced by a distant signal

Further details regarding the different types of stations are furnished in Chapter 26.

31.2.1 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.

31.2.2 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 bare 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.

31.3 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 as shown in Fig. 31.2.

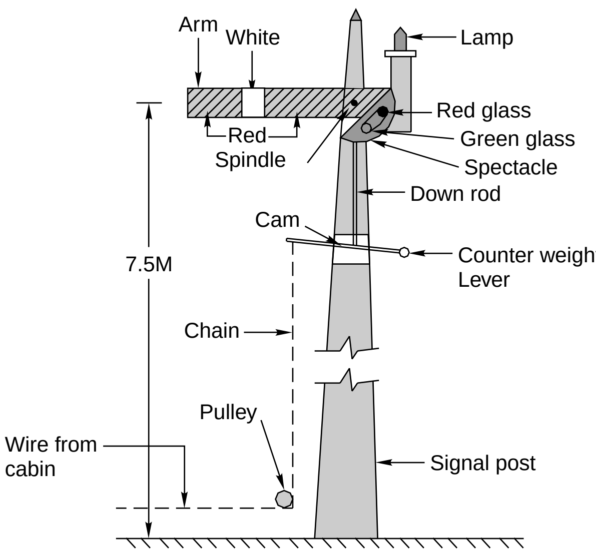


Fig. 31.2 Semaphore signal

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

With reference to lower quadrant signalling, the colour aspects of a semaphore signal and their corresponding indications when the arm of the signal is in two distinct positions are shown in Fig. 31.3 and also Table 31.3.

Lower quadrant semaphore signals move only in the fourth quadrant of a circle and have only two colour aspects. In order to provide the drivers with further information, upper quadrant signalling is sometimes used on busy routes. In this system, the arms of the semaphore signals rest in three positions and the signals have three colour aspects, namely, red, yellow, and green associated with the horizontal, 45° above horizontal, and vertical directions, respectively.

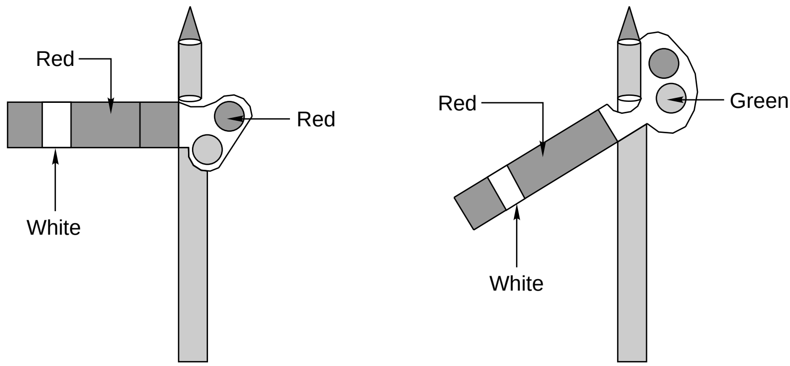


Fig. 31.3 Positions of semaphore signals

Table 31.3 Indications give by a semaphore signal

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

The signals are designed to be fail-safe so that if there is any failure in the working of the equipment, they will always be in the stop position. These signals are operated by hand levers or buttons located in a central cabin, which is normally provided near the station master's office. Semaphore signals are normally provided as outer signals, home signals, starter signals, advanced starter signals, and warner signals.

Permissive signal—warner or distant signal

In order to ensure that trains speed up safely, it is considered necessary that warning be given to drivers before they approach a stop signal. This advance warning is considered necessary, otherwise the drivers may confront a 'stop signal' when they least expect it and take abrupt action, which can lead to perilous situations. A warner or distant signal has, therefore, been developed, which is to be used ahead of a stop signal and is in the form of a permissive signal that can be passed even in most restricted conditions. In the case of a stop signal, the driver has to stop the train when it is in the 'on' position, but in the case of a permissive signal, the driver can pass through even when it is in the 'on' position. The most restrictive aspect of a permissive or warner signal is that the driver is not supposed to stop at the signal even when it is in the 'on' position.

The warner signal is similar to a stop signal except that the movable arm is given the shape of fish tail by providing a V-shaped notch at the free end; the white strip is also V-shaped.

In the case of signalling using coloured light, the permissive signal is distinguished from the stop signal by the provision of a P marker disc on the signal post.

The warner signal is intended to warn the driver of a train regarding the following aspects as explained in Table 31.4.

(a) That the driver is approaching a stop signal.
(b) To inform the diver as to whether the approach signal is in an 'on' or 'off' position.

Table 31.4 Position of warner arm or distant signal

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

* Also day and night indication for a coloured light signal.

The warner signal can be placed at either one of the following locations.

(a) Independently on a post with a fixed green light 1.5 m to 2 m above it for night indication.
(b) On the same post below the outer signal or the home signal.

In case a warner is fixed below an outer signal the various positions of the outer and warner signals and their corresponding indications are given in Fig. 31.4.

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.

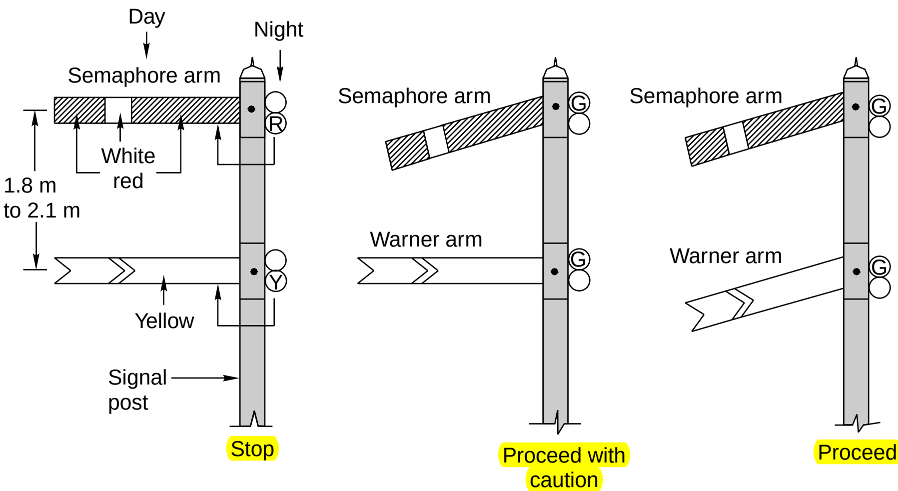


Fig. 31.4 Warner below an outer signal

In India, mostly three-aspect or four-aspect coloured light signalling is used. In the case of three-aspect signalling, green, yellow, and red lights are used. Green indicates 'proceed', yellow indicates 'proceed with caution', and red indicates 'stop' (Fig. 31.5).

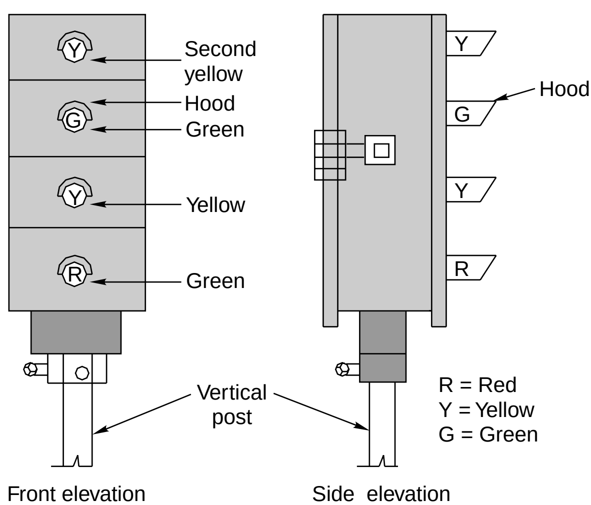


Fig. 31.5 Coloured light signals

In the case of four-aspect coloured light signalling, the interpretation of the colours are given in Table 31.5.

Table 31.5 Indications of coloured light signals

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

In conventional semaphore signals, the 'on' position is the normal position of the signal and the signals are lowered to the 'off' position only when a train is due. In the case of coloured light signals placed in territories with automatic signalling, the signal is always green or in the 'proceed' position. As soon as a train enters a section, the signal changes to 'Red' or the 'stop' position, which is controlled automatically by the passage of the train itself. As the train passes through the block section, the signal turns yellow to instruct the driver to 'proceed with caution' and, finally, when the train moves onto the next block section, the signal turns green indicating to the driver to 'proceed at full permissible speed'.

Thus it can be seen that each aspect of the signal gives two pieces of information to the driver. The first is about the signal itself and the second is about the condition of the track ahead or of the next signal. This helps the driver to manoeuvre the train safely and with confidence even at the maximum permissible speed.

Calling-on signal

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

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

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.

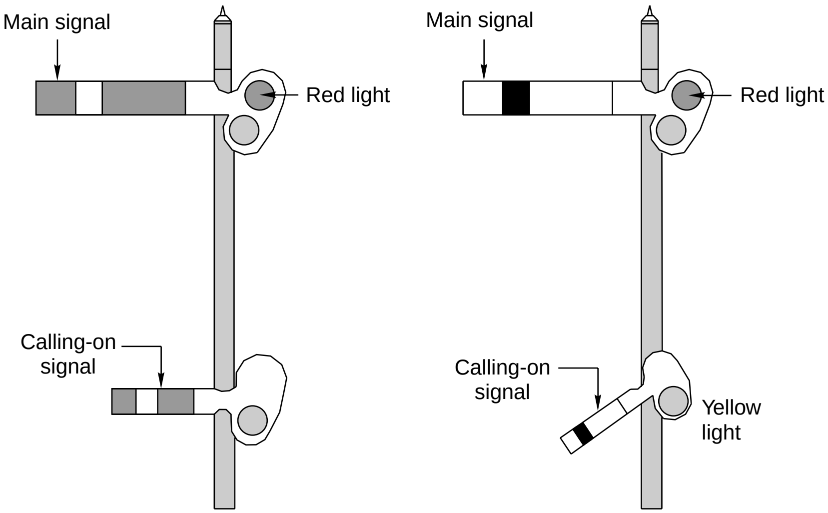


Fig. 31.6 Calling-on signal

Repeater signal

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

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

(b) A coloured light repeater signal.

(c) A rotary or disc banner type signal.

The 'off' positions of these three types of repeater signals are depicted in Fig. 31.7.

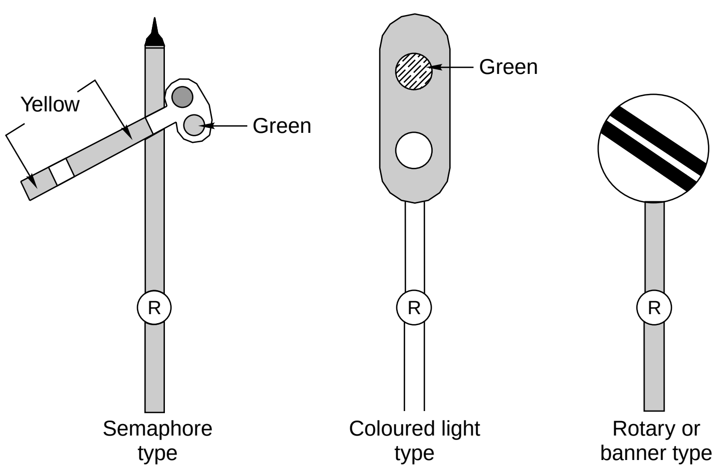


Fig. 31.7 Different Types of repeater signals

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. During the day the red band inclined to the horizontal plane and during the night the green light indicate that the signal is 'off' (Fig. 31.8).

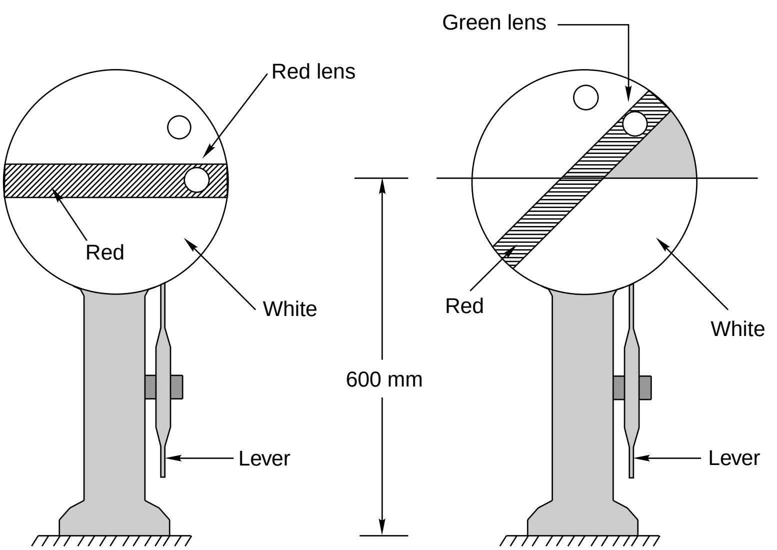


Fig. 31.8 Disc type of shunt signals

In colour light signalling areas, the shunt signal on an independent post consists of two white lights forming a line parallel to the horizontal plane. This indicates that the signal is 'on' or that there is danger ahead whereas two white lights forming a line inclined to the horizontal plane indicate 'off' or that the train can proceed (Fig. 31.9).

Point indicators

These are used to indicate whether points have been set for the main line or turnout side (Fig. 31.10). It essentially consists of an open box with two white circular discs forming two opposite sides of the box and green bands on the other two remaining sides. The box rotates automatically about a vertical axis with the movement of the points. The white disc indicates that the points are set for the main line. When the points are set for the turnout side, the green bands are visible. At night white light indicates a main line setting and green light signifies a turnout side setting.

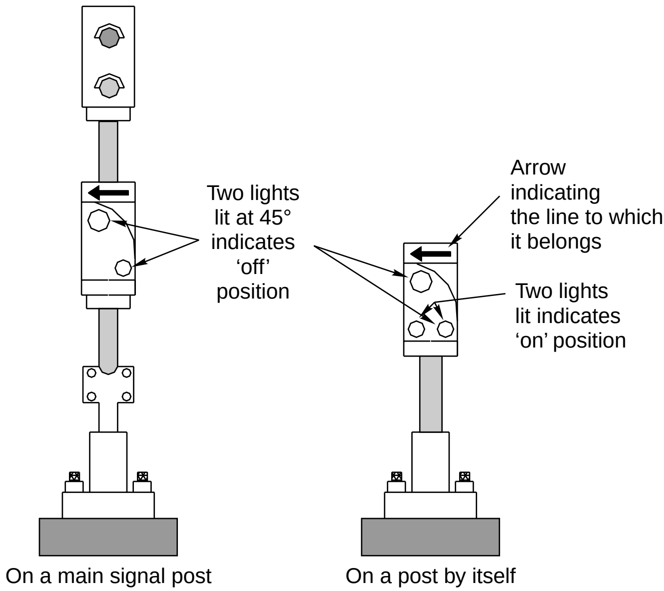


Fig. 31.9 Shunt signals in coloured light signalling area

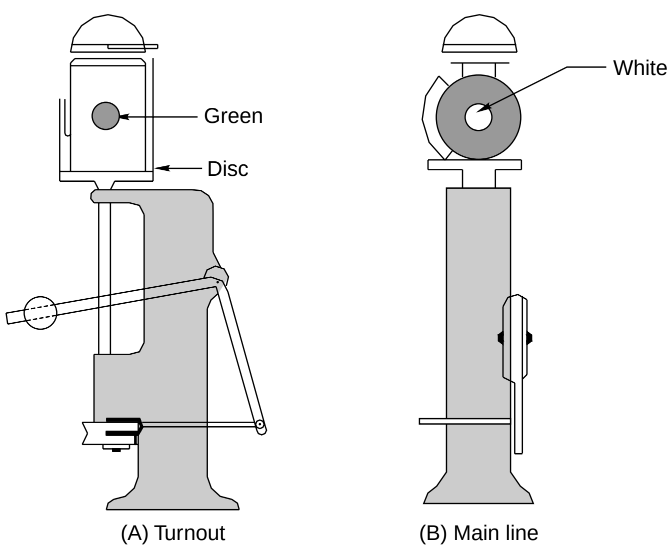


Fig. 31.10 Point indicators

Trap indicator

A trap is a device fitted on the track, which in its open position derails the vehicle that passes over it. When the trap is closed, the vehicle passes over it as it would over a normal track. A trap indicator reveals whether the trap is in an 'open' or 'closed' position. The details of the same are given in Table 31.6.

Table 31.6 Operation of a trap indicator

Position of trap	*Day indication*	*Night indication*
Trap open	Red target	Red light
Trap closed	Green target	Green light

Caution indicators

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

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

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

Stop indicator or stop board The driver has to stop the train at this location.

Termination indicator This indicates that the driver can assume normal speed and that the speed restriction zone has ended.

These indicators are also called temporary fixed engineering signals and are provided in the direction of the approaching train in the case of double lines and in both directions in the case of single lines.

Sighting board

A sighting board (Fig. 31.11) is an indication to the driver that he or she is approaching the first stop signal of a railway station. The function of a sighting board is to allow the driver to estimate the location of the next stop signal from the current location so that he/she starts applying brakes in case the first stop signal is in an 'on' position. As the requisite braking distance of goods trains and Rajdhani trains is greater than that of the passenger trains, the sighting boards for goods trains and Rajdhani trains are located farther and their design is different from that of sighting boards meant for passenger trains. The distances of sighting boards are listed in Table 31.7.

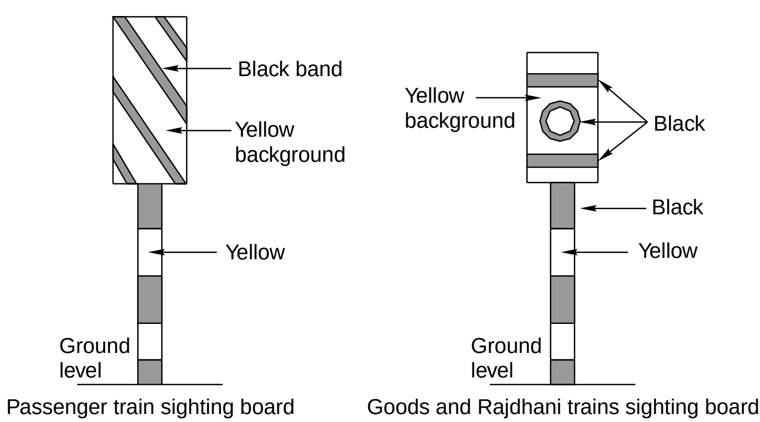


Fig. 31.11 Sighting board

Table 31.7 Positions of sighting boards

Type of sighting board	*Position*
Passenger train sighting board	1000 m for speeds over 72 km/h for BG tracks and 48 km/h for MG tracks
Goods trains and Rajdhani sighting board	1400 m for speeds over 72 km/h for BG tracks and 48 km/h for MG tracks

31.4 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. The various positions of the routing signal for a station with an outer signal, a home signal, and a warner signal that is provided below the outer signal are shown in Fig. 31.12.

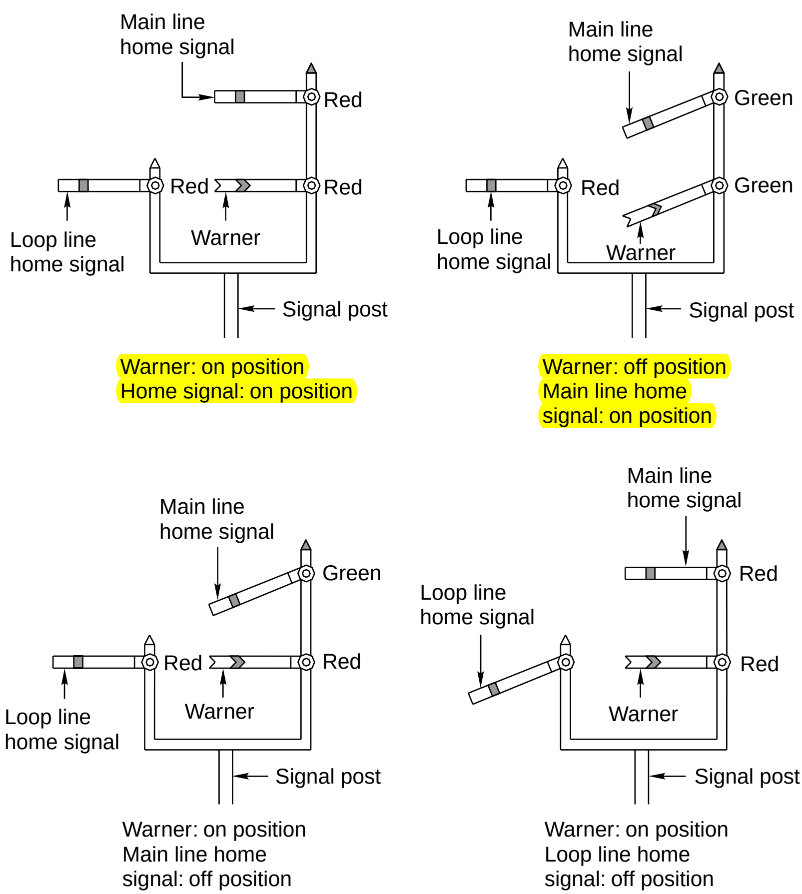


Fig. 31.12 Routing signals with outer, home, and warner signals

Route indicators can also be provided by including separate home signals for each line, with the main line home signal being placed the highest while all the other signals are placed at the same level.

In the case of coloured light signals, the home signal is provided with either a graphic lighted route indicator displaying the line number on which the train is to be received or different arms lighted by five lamps. These lamps form the arm, which is used for indicating a line, while there is no arm in the case of a main line as depicted in Fig. 31.13.

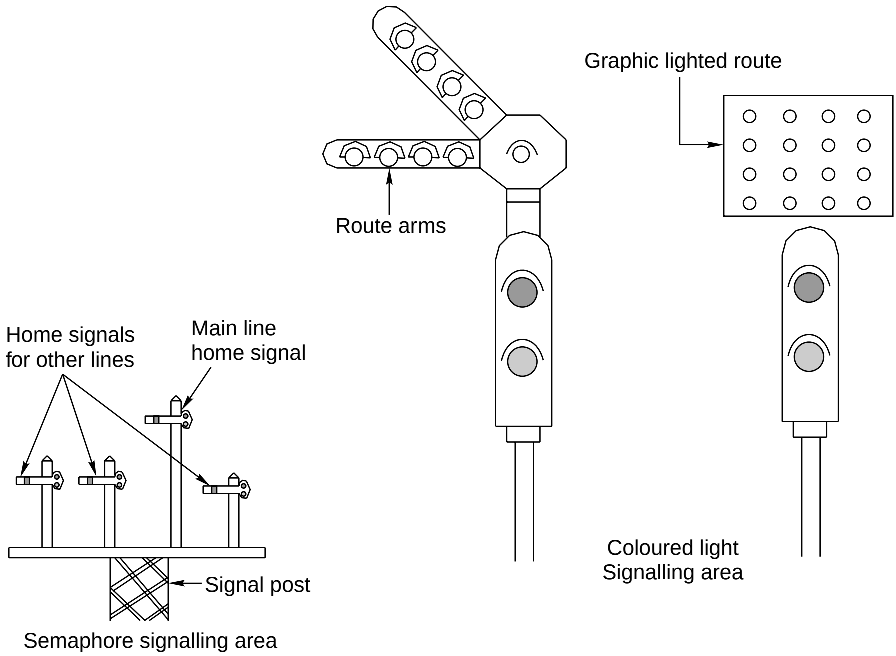


Fig. 31.13 Route indicators in semaphore and colour light signalling areas

Starter signal

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

Advanced starter signal

This is the last stop signal provided for the departure of trains from a station. The signal is provided about 180 m beyond the outermost points or switches and marks the end of the station limits. A block section lies between the advanced starter signal of one station and the outer signal of the next station. No train can leave the station limits until and unless the advance starter is lowered.

31.5 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

The comparison between mechanical and electrical signalling based on these four broad components is given in Table 31.8.

Table 31.8 Comparison of signalling systems

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

31.6 Mechanical Signalling System

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

31.6.1 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. See Fig. 31.14. The positions of the arm, the corresponding indications, and their meanings are listed in Table 31.9.

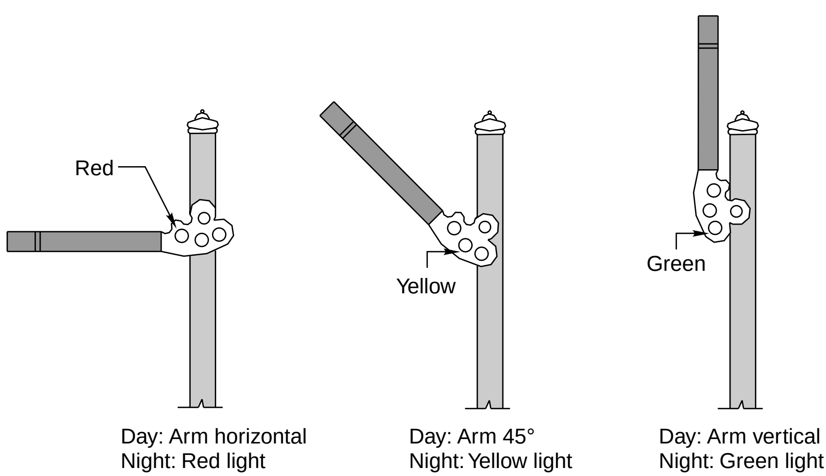


Fig. 31.14 Upper quadrant signalling

31.6.2 Points

Points are set mechanically and are kept in locks and stretcher bars. The mechanical arrangement for operating them includes a solid rod with a diameter of 33 mm running from the lever provided in the cabin and connected to the point through

Table 31.9 Details of upper quadrant signals

Position of arm		Indication	Interpretation
Distant/warner signal			
▸ Day	Horizontal	Caution	Proceed at a caution speed and be prepared to stop at the next signal
▸ Night	One yellow light		
▸ Day	Inclined 45° above horizontal	Attention	Proceed and be prepared to pass the next stop signal at a restricted speed
▸ Night	Two yellow lights in a vertical line		
▸ Day	Vertical	Clear	Proceed at full speed
▸ Night	One green light		
Stop signals			
▸ Day	Horizontal	ON	Stop dead
▸ Night	One red light		
▸ Day	Inclined 45° above horizontal	Caution	Proceed and be prepared to stop at the next signal
▸ Night	One yellow light		
▸ Day	Vertical	Clear	Proceed at full speed
▸ Night	One green light		

cranks. Owing to transmission losses, the operating points with rods is restricted to a specified distance from the cabin.

The following devices are used to ensure that the points are held rigidly in the last operated position under a moving train and to ensure absolute integrity of the same.

(a) Point locks to hold the point in the required position and to rigidly hold the point in the position of the last operation.
(b) Detectors to detect lock and switches.
(c) Lock bars to prevent the movement of points when a train is passing over them.

These devices are further discussed in the subsequent paragraphs.

Point locks

A point lock is provided to ensure that each point is set correctly. It is provided between two tongue rails and near the toe of the switch assembly. The point lock consists of a plunger, which moves in a plunger casing. The plunger is worked by means of a plunger rod, which is connected to the signal cabin through a lock bar. Additionally, there are a set of stretcher blades and each blade is connected to one of the tongue rails. Each blade has two notches and they move inside the plunger casing along with the tongue rails. When the points are set correctly for a particular route, the notch in the stretcher blade rests in its proper position and the plunger rod enters the notch, locking the switch in the last operated position.

Detectors

Detectors are normally provided for all the points for the following reasons.

(a) To detect any defect or failure in the connection between the points and the lever as well as any obstruction between the stock and the tongue rail.

(b) To ensure that the correct signal, which corresponds to the point set, is lowered.

(c) A detector can be mechanical or electrical. In the case of a mechanical detector, the point is held in the position of the last operation, which is achieved de facto by virtue of its design.

A detector normally consists of a detector box, which is provided with one slide for points and another set of slides for signals. The signal slides are perpendicular to the point slides. The slides are held suitably and no vertical movement of its same is possible. The signal slide has only one notch whereas the point slide has a number of notches depending upon the number of signals relevant to the points. The detector works on the principle that a particular signal can be lowered when the notch in that particular signal slide coincides with the notch in the point slide. For example, if the points are correctly set for the main line, the point slide moves and its notch comes to rest opposite the notch of the main line signal slide. The main line signal slide can then be pulled and the main line signal lowered. It may be noted here that the point slide will move and its notch will rest in its correct position only if the points are properly set and there is no obstruction in between.

The linear type (or slide type) of mechanical detector is used for single-wire signalling (Fig. 31.15), whereas the rotary type of detector (Fig. 31.16) is used for the double-wire signalling. A double-wheel detector is a rotary-type detector that rotates in a vertical plane. It detects the correct setting of points and, in addition, locks the points in the last operated position in the case of wire breakage.

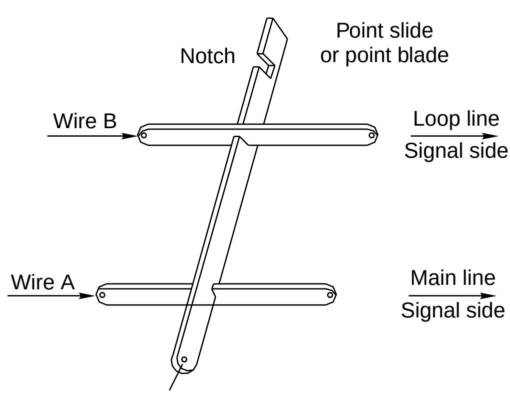


Fig. 31.15 Mechanical detector for single-wire signalling

Lock bar

A lock bar is provided to make it impossible to change the point when a train is passing over it. The lock bar is made of an angled section and its length is greater than that of the longest wheel base of a vehicle. Short revolving clips are provided to hold the lock bar in place on the inside face of one of the rails. The length of a lock bar is normally 12.8 m for BG and 12.2 m for MG sections.

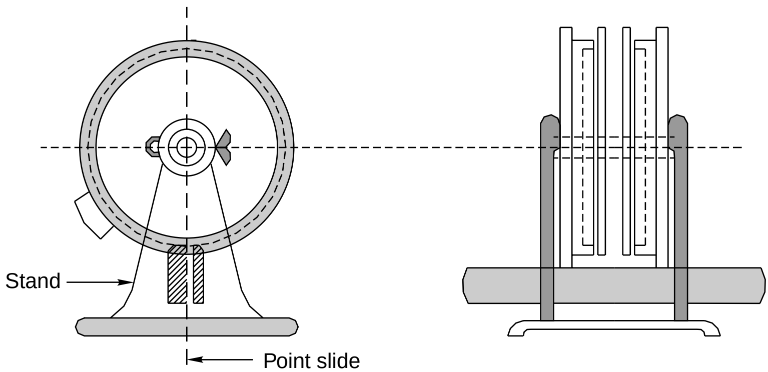


Fig. 31.16 Double-wheel rotary detector

The system is so designed that when the lever in the cabin is pulled to operate the locking device, the lock bar rises slightly above the rail level and then comes down. In the occurrence that a vehicle is positioned on the same location, the lock bar cannot rise above the rail level due to the flanges of the wheel and as such the point cannot be operated.

31.6.3 Different Transmission Systems

A signal is operated by pulling the associated lever and this action is transmitted through a single-wire or double-wire system. Initially, the single-wire system was the most popular way of operating signals and, in fact, some stations on Indian railways still use this system.

In the single-wire system, only one wire is stretched between the operating lever and the signal, whereas in the double-wire system a loop of two wires that run parallel to each other is wrapped over a drum lever and this system works on the principle of the pull and push arrangement.

Single-wire transmission

In the case of single-wire signalling, transmission is done with the help of the following equipment.

Lever frame A lever frame carries out the dual function of operating the single-wire system and actuating the interlocking in order to ensure safety. There are two types of lever frames, namely, a direct locking lever frame and a catch handle type lever frame, which are used for this purpose on the Indian Railways. The levers are pulled in order to operate the signals.

Signal transmission wire The entire transmission is done through an 8 or 10 SWG (standard wire gauge) galvanized steel wire. In places where the transmitting wire has to manoeuvre a turn, a multistandard galvanized steel wire is used, which is hauled over a horizontal or vertical wheel by pulling the lever. The arm of the signal remains as such while the lever is being pulled. When the lever returns to its normal position, the counterweight provided with the signal arm restores the wire back to its original position.

Cabin wire adjuster In order to accommodate the increase or decrease in the length of the cabin wire due to its expansion as a result of temperature variation, cabin wire adjusters are provided. If this is not done, it may result in inadequate lowering or drooping of the signal, thus giving rise to unsafe conditions.

Signal parts and fitting Signal parts and fittings are provided as per the details given in Fig. 31.2. The signal arm is brought to the 'off' position by a down rod. In the case of a breakdown of the signal transmission system, the signal arm is brought back to the horizontal position by means of a counterweight.

Limitations of single-wire signalling The single-wire signalling system does not give satisfactory performance in the operation of signals located at long distances. The signals do not operate correctly as they droop and do not get properly lowered, thereby endangering the trains. This defect develops due to the following reasons.

(a) Sagging of the wire due to its own weight.
(b) Expansion or contraction of the wire due to temperature variations.
(c) The elastic stretching of wires due to tension arising as a result of operating the lever.
(d) Entangling of the wire due to its slipping into the pulley stake and the horizontal and vertical wheels.
(e) Frequently breakage of the wire.

It has been noticed that the slightest slackness in attending to any one of these problems can cause the lowering of the signal, known as 'drooping', even when the lever is not pulled. On account of these defects, situations may arise in which a signal may not be lowered at all or a signal may not return to the 'on' position even after the lever has been restored to its normal position, if the wire gets entangled. As a result of these limitations, the single-wire signalling system can be used for operating signals from a range of only about 950 m.

Rod transmission In the single-wire transmission system, the signal is lowered or set in the 'off' position by pulling the lever. The signal returns to the 'on' position due to the effect of gravity as soon as the lever is restored to its normal position and the tension in the wire is released.

Where the operation of points is concerned, the points have to be set in either the normal or the reverse position; one of these positions can be attained through pulling and the other by pushing. Solid rods of 30 mm (1¼″) diameter are used to connect the levers to the points. The rods or pipes move on standard roller guides fixed at about 2-m (6-ft) intervals. A suitable crank is also used at every change of direction. The rods are subjected to expansion and contraction due to temperature variations.

Rod temperature compensator A rod compensator, also known as a temperature compensator, is provided to neutralize the effect of thermal. It consists of a pair of cranks, one acute and one obtuse, connected by a link and is so designed that it absorbs the expansion or contraction due to temperature variations. The compensator is normally placed at the centre of the rod up to a length of 36.5 m. If more than one compensator is required, these are placed at quarter points.

As can be seen in Fig. 31.17, the points, A or B may move left or right, but the total distance between them remains the same.

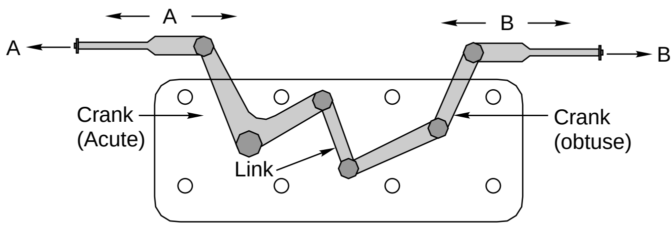


Fig. 31.17 Temperature compensator

Double-wire transmission system

In this system, power is transmitted with the help of two wires from the lever to operated units such as signals, points, locks, detectors, etc. Each wire consists of 8 to 10 SWG solid galvanized steel wires attached to pulley stakes, which are driven firmly into the ground. The two wires are connected between the lever and the signal to form a continuous loop. When the lever is operated, it leads to the wire getting pulled and when the lever is brought back to its normal position, it results in a push to the wire. This pull and push mechanism (Fig. 31.18) causes the drum to rotate in one direction when the lever is pulled and in the other direction when it is restored to its normal position. The rotary motion of the drum is then converted into linear movement by the use of cams and cranks and this finally actuates the signal, as illustrated in Fig. 31.19, which shows the complete double-wire transmission system.

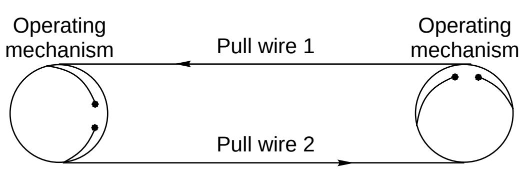


Fig. 31.18 Double-wire mechanism

Advantages of double-wire transmission The main advantages of double-wire transmission over single-wire transmission are enumerated here.

(a) Operating a double-wire transmission system is easier.
(b) A double-wire transmission system permits multi-aspect signalling.
(c) The range of operations of the double-wire transmission system is greater.
(d) There is no drooping of signals in double-wire transmission. This results in better safety.
(e) The operating cost of a double-wire transmission system is less.

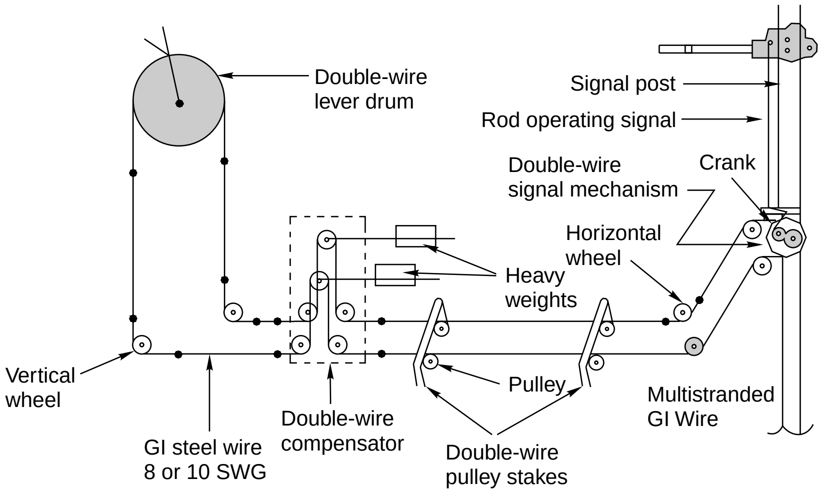


Fig. 31.19 Double-wire transmission system

Table 31.10 compares a signal-wire and a double-wire signalling system. The special features of a double-wire signalling system are as follows.

Table 31.10 Comparison of transmission systems

Feature	*Single-wire signalling*	*Double-wire signalling*
Drooping of signals	Can occur	No drooping
Outside interference	Higher possibility	Lower possibility
Method of signal return to the 'on' position	By the action of on gravity	By pulling back the lever
Range of operation for signals	950 m	1200 ms for a 500-mm drum
Damage to down rod	More frequent	Less frequent
Adjustment of length due to temperature variation	By manually operated cabin wire adjuster	Automatically done by double-wire compensator
Requirement of cabins	Two	One
Cost aspect	Not so costly	Costlier
Maintenance	Requires more maintenance	Less maintenance required
Effect of weather	Affected considerably	Immune
Safety aspect	Safe	Safer

(a) *Double wire compensators* are provided to perform the following functions.
   (i) To maintain constant tension in the transmission system by adjusting the changes in length caused by temperature variations.
   (ii) To provide protection against wire breakage. Whenever a wire breaks, the following compensator ensures that the signal is brought to the 'safe' position.

(b) Jockey weights are added to the main compensator weight to cater to a greater operating force.
(c) Coupling devices are provided to detect the couplings of two levers in a common transmission.
(d) Double-wire detectors are provided to detect the correct setting of the points and locks.

31.6.4 Operating Mechanism

In mechanical signalling, the signals and points are operated mechanically. The operation of these units, therefore, requires sufficient amount of power. To facilitate the quick and smooth operation of these equipment, levers are used in single-wire as well as in double-wire mechanical transmission. These levers may be installed individually near an operated unit such as a point or a signal or may be grouped together in a lever frame depending upon the type and standard of signalling. Lever frames may be of the following types.

Single-wire lever frame

In this type of lever frame, the lever is a bar fulcrumed on a shaft. The longer end of the bar rests towards the lever while the shorter end rests towards the signal or the point in order to gain mechanical advantage. Pulling the lever results in a movement of 200 mm in the case of points and 300 mm in the case of signal operation. All the levers that are required to operate different units such as points and signals are grouped together on a common fulcrum shaft in a compact lever frame, which is kept below the level of the operation platform. Only a convenient length of the lever is allowed to protrude beyond the platform to facilitate easy operation. A latch arrangement is also provided with the lever arm to maintain the lever in the position in which it was last operated.

Double-wire lever frames

Unlike single-wire systems, a double-wire transmission system is in the form of a loop, one end of which is wrapped across a drum that is provided with an arm. When this arm is rotated about the centre of the drum, it imparts a stroke of 550 mm or 600 mm depending upon the type of lever used. There are six types of double-wire levers used on Indian Railways that impart strokes of 500 mm to 600 mm.

When referring to points, normally a 500-mm stroke drum is capable of operating all the equipment satisfactorily up to a distance of 500 m. In the case of any difficulty, 600-mm stroke levers may be used.

The interlocking of these operating mechanisms is discussed in Section 31.9.

31.6.5 Monitoring Units

Monitoring units are provided to ensure that points are set properly and locked for the safe passage of trains. These units are also sometimes used to monitor the passage of trains. Detectors and treadles are used as monitoring devices on Indian Railway. Detectors have been discussed in Section 31.6.2.

Treadle for monitoring passage of train

It is not always possible for a train to pass immediately after the route has been set for its reception or departure and the signals have been placed in the 'off' position. There is generally a time gap between these two events. During this intervening period, the operator has to conduct many other operations in the yard such as the shunting of some other train, monitoring the movement of other trains, and booking tickets, and in the process, the operator is likely to forget about the passage of the train on the route set by him. In order to eliminate human error, some devices are provided to monitor the presence or passage of a train over a defined portion of the track. Most of these devices are either electrical or electronic. However, the basic electro-mechanical device used for monitoring the passage of a train is a *treadle*. A treadle unit is fastened with the rails. The passage of the train deflects the point of contact, which is transmitted to the cabin thereby proving and confirming the passage of the train.

31.7 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.

31.7.1 Operated Units

The operated units consist of signals and points. The electrical signalling system is either coloured light signals or signals with semaphore arms operated by electric motors.

A point is operated by converting the rotary movement of the electrical point machines fastened on the sleepers near the point into a linear push or pull force. There are low-voltage point machines operated with a 24-V dc supply and high-voltage point machines operated using a 110-V dc supply. The operation of a point machine involves first unlocking the lock, bringing the point from normal to reverse or reverse to normal as the case may be, and then locking the point once again. The operating time of these point machines varies between 3 and 5 sec.

31.7.2 Transmission Medium

The medium of transmission for operating electrical equipment is either an overhead alignment or an underground cable. The overhead alignment is used when the number of conductors is limited. In areas provided with 25-kV ac traction, it is not possible to use overhead alignments due to the induced electromotive force (EMF) generated as a result of electrostatic and electromagnetic induction. In big yards, cables are used as a medium of transmission for the operation of point machines. The cables are either hung on hooks and run by the side of the track or laid underground. In areas provided with ac traction, under ground screened cables are used.

31.7.3 Operating System

Normally push buttons and rotary switches are used for operating signalling equipment that work on electricity. The complete yard layout is represented on the face of a console. Signals, tracks, points, and the gates of level crossings are depicted in their geographical positions on this console and the positions of these switches are then marked at the foot of signals and on various tracks.

Complete interlocking is achieved through electromagnetic switches known as *relays*. The two methods of interlocking available are panel interlocking or route relay interlocking. The details of these two systems of interlocking are given in Section 31.9.

31.7.4 Monitoring System

It mainly consists of point detectors, track circuits, and axle counters, all of which are discussed here in detail.

Electrical point detector

The electrical point detector detects and ensures that points are properly set. It also works on a ‘slide system’ as used in the mechanical system. These slides are so adjusted that a gap of 3 mm is left between the switch rail and the stock rail so that the two do not come is contact and, therefore, it is not possible to turn the signal off at any time.

Track circuit

The track circuit is an electric circuit formed along with the running rails and connected to the signal and cabin. Its function is to indicate the presence of a train (or vehicle) on the track. In order to set up a track circuit, the ends of the rails forming the circuit are isolated by insulating the rail joints. The rails are laid on wooden sleepers so that they are electrically insulated from each other. The ends of the rail on one side of the track are connected to a battery through resistances, etc., while on the other side of the track, the ends of the rails are connected to a relay. When the track is free, energy from the battery reaches the relay and energizes it. As soon as the track is occupied, the two rails are short-circuited because of the wheels and axle of the train and the relay does not get any feed from the battery. It, therefore, gets de-energized, thereby breaking the circuit connected with the signals, thus ensuring that the necessary signals are set to indicate danger. The various types of track circuits used on the Railways are as follows.

(a) Direct current track circuit
(b) Alternating current track circuit
(c) Electronic track circuit

Axle counters

As already mentioned, two consecutive rails need to be insulated from each other for setting up a track circuit. The most essential requirement for track circuiting is the use of wooden sleepers. Due to the shortage of wooden sleepers on Indian Railways, an attempt is being made to progressively use a device known as an *axle counter*, which can be used as a substitute for track circuiting to detect the presence or absence of a vehicle on a track. A pair of rail inductors are installed at either end of the track for counting the axles. As soon as a train enters the track section from one end, the number of axles entering the section are counted automatically. Similarly, when the train leaves the track section at the other end, the axles are counted once again at the other end. If the same number of axles are counted at both the ends, it indicates that the section is free or unoccupied. If the number of axles counted at the exit end are less than the axles counted at the entrance to the section, it means that the section is still occupied.

31.8 Systems for Controlling Train Movement

The system adopted for controlling the movement of trains should be such that it allows the trains to run in either direction as well as facilitates faster trains to overtake slower trains, thus ensuring the complete safety of trains. The following systems are chiefly used for controlling the movement of trains on Indian Railways.

Time interval system

In this system, there is a time interval between two successive trains. A train is dispatched only after sufficient time has elapsed since the departure of the previous train. This system works fine just as long as everything goes well with the previous train, but if there is a mishap and the previous train is held up, the system fails, jeopardizing the safety of the trains.

Space interval system

In this system, there is a space interval between two consecutive trains. Only one train is permitted to occupy a particular length of the track. A succeeding train is permitted to occupy the same track length from either side only after the first train has cleared it. This system guarantees safety as only one train is in motion at one time.

31.8.1 Methods of Controlling Train Movement

Based on these systems, the following methods are adopted for controlling the movement of trains on Indian Railways.

One-engine-only system

This system permits only one train to remain in a section at one time. The movement of trains is controlled with the help of a *wooden staff* or a *token* with suitable identification marks, which are in the possession of the driver of the train. As the same object cannot be at two places at the same time, the safety of trains is fully ensured. This system is possible only on short branch lines that have limited traffic. Normally there is only one train, which works to and fro on the same section. The system fails if it becomes necessary to dispatch more than one train in the same direction. This system does not require a 'line clear' directive.

Following-train system

In this system, trains follow each other after a time interval that is generally less than 15 min. Trains scheduled after the first train can run at a maximum speed of 25 km/h. As an adequate time interval is kept between two successive trains, safety is ensured to a limited extent. The system is used under the following circumstances.

(a) In the case of emergencies such as the failure of block instruments and the telephone system
(b) In short double-line stretches

Pilot guard system

In such a system, one person, known as the *pilot guard*, accompanies a train by riding on the foot plate of the engine (or gives a ticket personally to the guard of the train, which is authority to proceed) and returns to the same station with another train. The pilot guard is normally identified by his or her prescribed uniform, which is red in colour, or the badge that he or she wears and is an authority for the train to proceed. Even in this system trains can follow each other after a fixed time interval of not less than 15 min. The system is applicable in short single-line sections or in the case of failure of communication between two stations.

Train staff and ticket system

This system is similar to the pilot guard system. The authority to proceed in this case is either a wooden staff or a ticket. There is only one wooden staff for a section and the same is kept at one of the two stations on that section. Each station has a ticket box which contains printed tickets and is kept locked. The wooden staff is interlocked with the box in a way that it cannot be taken out so long as the box is locked. A train can only be dispatched from the station that has the staff. In case only one train is to leave the station, then the staff is handed over to the driver of the train. If more than one train is to be dispatched from the same station, the preceding trains are dispatched on the authority of the ticket while the last one is dispatched along with the staff. The time gap between two successive trains is not less than 15 min and the speed of the trains is restricted to 25 km/h. A similar system is followed for dispatching trains from the other station. In this system, the safety of the trains is ensured on account of the fact that only one ticket can be issued at one time and the driver insists on seeing the staff before accepting the ticket as his authority to proceed.

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.

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.

Single-line tokenless 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, tokenless 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.

Double-line block instruments In a double-line section, traffic is unidirectional. The block instrument comprises of a commutator handle and two indicator needles placed in vertical alignment. In order for the block instrument to work on a double line, the station master turns his block instrument commutator to the 'Line clear side'. This causes the electrical circuit to make contact in such a way that the advanced starter of the dispatching station can be turned off.

Working details Take an example of a block section AB situated between two stations A and B on a single-line section (Fig. 31.20). A train is waiting at A to enter the section AB. The procedure is as follows.

1. The station master of station A establishes telephonic contact with the station master of station B with the help of the block instrument and requests the station master of station B to grant a line clear, i.e., permission so that he can dispatch train A.

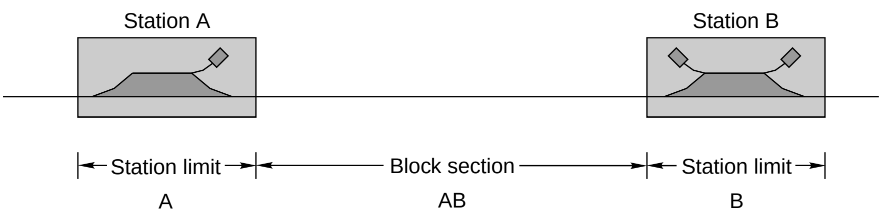


Fig. 31.20 Block section AB between stations A and B

2. Once the station master at station B has ensured that the line is clear according to the prescribed norms, he agrees to receive the train and grants a line clear. For this, he gives a private number and operates the block instrument of his station in a prescribed manner. The station master at station A notes this private number and simultaneously operates his block instrument so that a 'ball token' is extracted from the block instrument.
3. The station master at station A then allows the point to be set, lowers the signal and hands over the 'ball token' to the driver of the train waiting at station A.
4. The station master at station B also gets the points set and lowers the signal for the line on which the train is to be received.
5. The train then starts from station A and enters the block section AB.
6. The train reaches station B. The driver of the train hands over the ball token to the station master of station B. After ensuring that the entire length of the train has been received, the station master at B pockets the ball token in the block instrument. He then informs the station master at station A of the arrival of the train on a private number as proof of the same. The points at station B are then set as they were before and the reception signals restored to their normal positions.
7. The same procedure is repeated when the train has to enter a block section BC.

The system is absolutely safe and works on the principle of providing space intervals. Most stations on Indian Railways work on this principle. The following are the essential features of the absolute block system.

(a) No train is allowed to leave a station unless ‘permission to approach’ has been received in advance from the block station.

(b) On double lines, permission to approach is not given until the line is clear, not only up to the first stop signal of the next station, but also for an adequate distance beyond it.

(c) On a single line, ‘permission to approach’ is not given until the following conditions are satisfied.

  (i) The line is clear of trains running in the same direction, not only up to the first stop signal of the next station, but also for an adequate distance beyond it.

  (ii) The line is clear of trains running in the opposite direction.

(d) When two trains are running in the same direction on the same track, permission to approach should not be given to the second train till the entire length of the first train is within the limits of the home signal, the ‘on’ status of all the signals behind the first train has been restored, and the line is clear, not only up to the first stop signal of the station, but also up to an adequate distance beyond it.

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.

  (i) The signal should not assume the ‘off’ position unless the line is clear in advance, not only up to the next stop signal, but also for an adequate distance beyond it.

  (ii) The signal should automatically turn on as soon as the train passes it.

31.9 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.

31.9.1 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.

31.9.2 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.

Table 31.11 lists the stipulations laid down by Indian Railways for signals, isolation, points, and interlocking arrangements. The details of each of these interlocking standards are enumerated in Table 31.12.

Table 31.11 IR's stipulations for interlocking

Modules	*Stipulations regarding*
Signals	The number and type of signals
Isolation	The standard of isolation of the main line from other passenger lines so that no trains come onto the main line due to human error
Points	The type of points and fittings to be used on the main line and on other passenger lines
Interlocking arrangement	The type of interlocking required

31.9.3 Methods

There are basically two methods of interlocking as explained below.

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.

Table 31.12 Details of the different standards of interlocking

Standard of interlocking and maximum permissible speed	*Details of signals*	*Type of isolation*	*Locking of points*	*Details of interlocking*
Zero or non-interlocked (15 km/h)	Outer and home signals in either direction	Main line not required to be isolated from other passenger lines	(a) A clamp and padlock for locking the switch rail (b) A gauge tie plate where steel sleepers are not provided	Non-interlocked
Standard I interlocking (50 km/h)	(a) Outer and bracketed home signals for two-aspect signalling (b) Distant and home signals for MAUQ signalling	Main line not required to be isolated from other passenger lines	(a) Approved type of lock and key (b) Arrangements for locking each switch independently (c) Arrangement for protecting the points from getting blocked during the passage of trains	(a) Interlocking between facing points and signals by means of a key lock. Signal cannot be turned off till facing points are correctly set and locked (b) Signal cannot be lowered till trap switc, if any, is closed
Standard II interlocking (75 km/h)	(a) Outer, warner, and bracketed home signals for two-aspect signalling (b) Distant, home, and starter signals for MAUQ signalling	Main line is isolated from other passenger lines	(a) A plunger-type facing point lock (b) Same as (b) and (c) for standard I interlocking	(a) Interlocking between point and signal may be direct or indirect (b) Station master provided with control over home and last stop signal
Standard III interlocking	(a) Outer, warner, bracketed home, and	Main line is isolated from other passenger lines	(a) A plunger-type facing point lock (b) Same as (b)	Direct type interlocking is provided between signals and

(*contd*)

Table 31.12 (*contd*)

Standard of interlocking and maximum permissible speed	*Details of signals*	*Type of isolation*	*Locking of points*	*Details of interlocking*
(same as section speed)	starter signals in two-aspect signalling (b) Distant, home, and starter signals for MAUQ* and MACL† signalling		and (c) for standard I interlocking	points, which is established by means of interlocking frames located in the cabin

* Multiple-aspect upper quadrant signalling.
† Multiple-aspect coloured light signalling.

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.

31.9.4 Different Cases

The following cases of interlocking are encountered in practical application.

Normal locking In this case, pulling one lever locks the other lever in its normal position.

Back locking or release locking In this case, when the lever is in its normal position, it also blocks the other lever in its normal position, but when this lever is pulled it releases the other lever, which can then also be pulled. Furthermore, once the second lever is also pulled, the first lever gets locked in the 'pulled' position and cannot be returned to its normal position unless the second lever is restored to its normal position.

Both wall locking In this case, once a lever is pulled, it locks the other lever in its current position, i.e., in the normal or pulled position.

Special or conditional locking In this case, the pulling of one lever locks the other lever only when certain conditions are fulfilled, say the third lever being in a normal or pulled position as the case may be.

31.9.5 Mechanical Interlocking of Points and Signals of a Two-line Railway Station

To understand the mechanical interlocking of the points and signals of a two-line railway station, let us take the case of a typical railway station that has both a main line and a loop line. It is provided with a home signal 1 operated by lever 1 for the main line and a home signal 2 operated by lever 2. Point 3 is set for the main line when lever 3 is in its normal position and for the loop line when lever 3 is pulled. In its pulled position lever 4 locks point 3 in either position (normal or reverse) by pushing the plunger of the facing point into the 'lock in' position. The essentials of this interlocking system are as follows (Fig. 31.21).

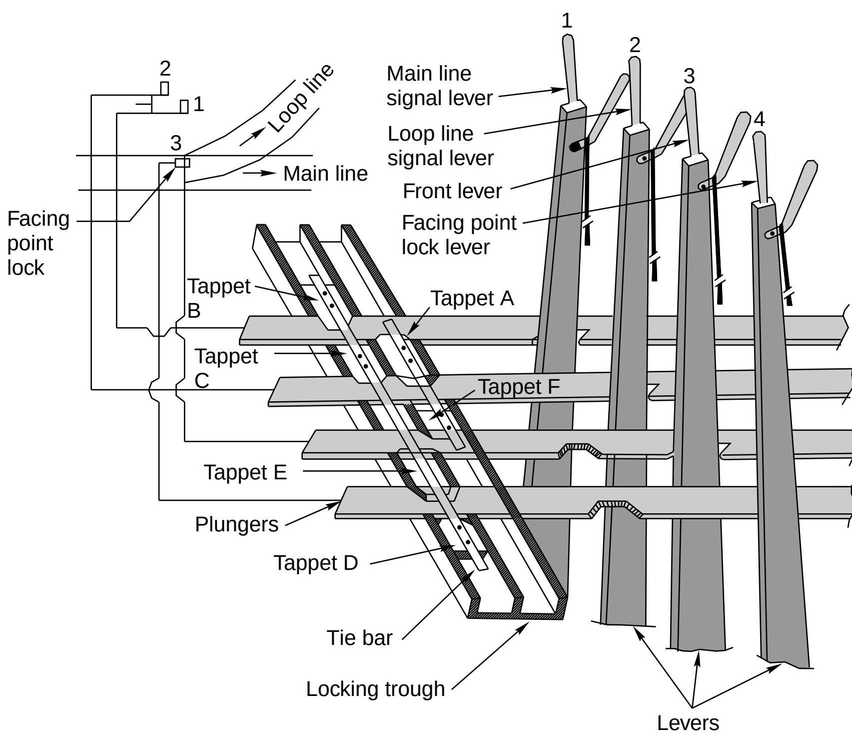


Fig. 31.21 Interlocking of points and signals of a two-line railway station

(a) It should not be possible to turn off both the signals, i.e., 1 and 2 at the same time, i.e., the train should be received either on the main line or the loop line at any given time. To achieve this, tappet A is forced out of the plunger of lever 1 when lever 1 is pulled. The tappet enters the notch of the plunger of lever 2 and cannot move out until lever 1 is pulled. This prevents lever 2 from getting pulled when lever 1 is pulled. The reverse of this situation is also true.

(b) It should not be possible to turn a signal off until and unless the point is set and locked. If an effort is made to pull either lever 1 or 2, the same cannot be pulled. This is because of the following reasons. Tappets B and C are rivetted with a tie bar that is in turn connected with tappet D. Since tappet D is butting against the face of the plunger of lever 4, tappet B or C cannot be moved. This plunger can move only when lever 4 is pulled, thereby bringing the notch of the plunger opposite tappet D. Once this happens, it is not possible to restore the position of lever 4 till lever 1 or 2 has been brought back to its normal position. This is a case of *release locking.* Levers 1 and 2 are released by pulling lever 4, which in turn locks the point.

(c) Lever 4 is a lock lever and locks point 3 in either position. The same can be visualized for tappet E.

(d) Similarly, the main line home signal lever 1 cannot be pulled if point lever 3 is pulled, i.e., if it is set for the loop line, as the tappet F cannot be pushed, which allows lever 1 to be pulled when the notch in the plunger of lever 3 that lies opposite tappet F has been shifted from its position due to the pulling of lever 3. With lever 3 normal, lever 1 can be pulled conveniently, simultaneously resulting in the locking of lever 2 in it normal position by tappet A.

This example indicates that, with proper planning, it is possible to mechanically interlock the movement of points and signals and thus ensure complete safety.

31.9.6 Electrical Interlocking of Points and Signals of a Two-line Railway Station

Electrical interlocking is achieved through electric switches known as relays. The manipulation of relays achieves interlocking, whereas lever locks that are attached with the levers in place of plungers or in addition to plungers prevent a lever from getting pulled, or allow it to get pulled or normalized if the interlocking so permits.

Relays use the simple principle of electromagnetism, whereby a soft iron core wrapped inside a wire coil turns into electromagnet when current is passed through the wire. An armature is attached to this electromagnet, which has a number of finger contacts that come into contact with each other when the armature is attracted to the magnet and break the contact when the armature is not attracted to it. The whole system is housed in a glass or metal box and is known as *relay*.

31.10 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.

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 intercabin 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.

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.

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.

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.

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.

Summary

Signals are used to regulate the movement of trains and interlocking ensures the safe working of signals. There are many different kinds of signals and each one of them gives vital information regarding track conditions. These signals have separate indicators for day and night. There are various methods of interlocking starting with the simple key method to the advanced automatic train control system. With advancement in signalling as well as interlocking systems, it has become possible to run trains at smaller intervals, ensuring optimum use of the track capacity.

Review Questions

1. Give the classification of signals according to their locations in station yards along with suitable sketches.
2. (a) What are the objectives of interlocking? Explain the tappet and lock system of interlocking.
   (b) Briefly describe the absolute block system of controlling the movement of trains for single and double lines.
3. What essential purposes are served by signalling and interlocking? What is meant by route relay interlocking?
4. (a) Briefly describe the locations and purposes of the following signals: (a) warner, (b) outer, (c) home, (d) starter, (e) advance starter.
   (b) What are the minimum signal requirements in each direction for a two-aspect signalling system in class A, B, and C stations?
   (c) What are the essentials of interlocking? Distinguish between direct and indirect interlocking.
5. (a) Explain what you understand by interlocking in a railway system.
   (b) What purposes does the lock bar serve?
   (c) Distinguish between the following pairs of terms.
      (a) Repeating and co-acting signals
      (b) Warner and distant signals

(c) Absolute block system and automatic block system
(d) Track circuit and rail circuit

6. Describe the three aspects in upper quadrant signalling. Briefly describe one method of interlocking used on Indian Railways.
7. Write short notes on (a) absolute block system (b) rudimentary interlocking, and (c) MAUQ signalling. How many standards of interlocking are in vogue on Indian Railways? What requirements must be met by each of them?
8. Briefly describe semaphore signals and coloured light signals.
9. Explain with the help of sketches the use of the compensator device in signalling with regard to the thermal expansion of wires.
10. Mention the objectives of signalling. How are signals classified? Mention the functions of each signal.