IMPORTANCE OF TRANSPORTATION

IMPORTANCE:-

The importance or necessity of transportation can be easily judged from the following purposes or advantages of roads:-

1. They facilitate, conveyance of people, goods, raw-materials, manufactured articles etc. speedily and easily in the different parts of a country.
2. They act as the only source of communication in regions of high altitudes i.e. in mountainous regions.
3. They help in growth of trade and other economical activities in and outside the villagers and towns by establishing contact between towns and villages.
4. They help in providing efficient distribution of agricultural products and natural resources all over the country.
5. They help in price stabilization of commodities due to mobility of products all over the country.
6. They help in cultural and social advancement of people and making the villagers active and alert members of the community.

community.

7. They help in promoting the cultural and social ties among people living in different part of a country and thus strengthen the rational unity.
8. They help in providing improved medical facilities quickly to human beings, especially to those who live in rural areas.
9. They provide more employment opportunities.
10. They enhance land value and thus bring better revenue.
11. They help in reducing distress among the people, caused due to famine, by suppling them food and clothing quickly.
12. They play a very important role in the defense of a country during war days.

Rail Transport:

Advantages of Rail transport:

- ✓ It is a convenient mode of transport for travelling long distances.
- ✓ It is relatively faster than road transport.
- ✓ It is suitable for carrying heavy goods in large quantities over long distances.
- ✓ Its operation is less affected by adverse weathers conditions like rain, floods, fog, etc.

Limitations of Railway transport:

- ✓ It is relatively expensive for carrying goods and passengers over short distances.
- ✓ It is not available in remote parts of the country.
- ✓ It provides service according to fixed time schedule and is not flexible for loading or unloading of goods at any place.
- ✓ It involves heavy losses of life as well as goods in case of accident.

Road Transport

- **Advantages**
  - ✓ It is a relatively cheaper mode of transport as compared to other modes.
  - ✓ Perishable goods can be transported at a faster speed by road carriers over a short distance.
  - ✓ It is a flexible mode of transport as loading and unloading is possible at any destination. It provides door-to-door service.
  - ✓ It helps people to travel and carry goods from one place to another, in places which are not connected by other means of transport like hilly areas.
- **Limitations of Road transport**
  - ✓ Due to limited carrying capacity road transport is not economical for long distance transportation of goods.
  - ✓ Transportation of heavy goods or goods in bulk by road involves high cost.

Water Transport

- **Advantages:**
  - It is a relatively economical mode of transport for bulky and heavy goods.
  - It is a safe mode of transport with respect to occurrence of accidents.
  - The cost of maintaining and constructing routes is very low most of them are naturally made.
  - It promotes international trade.
- **Disadvantages:**
  - The depth and navigability of rivers and canals vary and thus, affect operations of different transport vessels.
  - It is a slow moving mode of transport and therefore not suitable for transport of perishable goods.
  - It is adversely affected by weather conditions.
  - Sea transport requires large investment on ships and their maintenance.

Air Transport:

- **Advantages:**
- ✓ It is the fastest mode of transport.
- ✓ It is very useful in transporting goods and passengers to the area, which are not accessible by any other means.
- ✓ It is the most convenient mode of transport during natural calamities.
- ✓ It provides vital support to the national security and defence
- **Disadvantages:**
- ✓ It is relatively more expensive mode of transport.
- ✓ It is not suitable for transporting heavy and bulky goods.
- ✓ It is affected by adverse weather conditions.
- ✓ It is not suitable for short distance travel.
- ✓ In case of accidents, it results in heavy losses of goods, property and life.

Characteristics of Road Transport

It is an accepted fact that of all the modes the transportation,road transport is the nearest to the people.The passenger and the goods have to be first transported by road before reaching a railway station or a port or an airport.The road network alone could serve the remotest villages of the vast country like our.

The Characteristics of Road Transport are briefly listed here.
*Roads are used various types of road vehicles,like passenger cars,buses,trucks two and three wheeled automobiles ,pedal cycles and animal drawn vehicles.But railway tracks are used only by rail locomotives and wagons,water ways are used by only ships and boats

*Road transport requires a relatively small investment for the government.Motor vehicles are much cheaper than carriers like rail locomotives and wagons,water and air carriers. and air carriers.Construction and maintenance of roads is also cheaper than that of railway track,docks,harbours and airports.

*Road transport completely offer an freedom to road users to transfer the vehicles from one lane to another. and to from one road to another according to the need and convenience.This flexibility of changes in location,direction,speed and timings of travel is not available to other modes of transport.

*In particular for short distance travel,road transport saves time.Trains stop at junctions and main stations for comparatively longer time.

*Speed of movement is directly related with severity of accident.The road Safety decreases with increase dispersion in speed.Road Transport is subjected to high degree of accidents due to flexibility of movements offered to the user.Derailment of railway locomotives and air planes and air crashes are not uncommon.They are in fact more disastrous.

*Road transport is the only means of transport offer itself to the whole community.

What is Multimodal transport?

- Multimodal transport is the articulation between different modes of transport, in order to more rapidly and effectively transfer operations of materials and goods

- Multimodal transport is that in which it is necessary to use more than one type of vehicle to transport the goods from his place of origin to their final destination, but mediating a single contract of carriage.

- Within this overall framework, we distinguish intermodal transport (using different types of transport but using a single measure of load) and combined transport (the responsibility is assumed by different operators).

- Multimodal transport is effected by a multimodal transport operator who holds a multimodal transportation contract and assumes responsibility for compliance as carrier.

The merits of multimodal transportation

* Minimizes time loss at trans-shipment points Provides faster transit of goods
* The faster transit of goods

Definition:

Mass transit system refers to public shared transportation, such as trains, buses, ferries etc that can commute a larger number of passengers from origin to destination on a no-reserved basis and in lesser time. It can also be termed as *Public Transport*.

Rapid transit is an important form of mass transit system such as subways and surface light rail systems, designed for commuting inter-city or intra-city. Mass transit may be based on fixed route system such as subway trains, metros or non-fixed route system such as buses. It is potentially more economical, eco-friendly and less time consuming. In addition, it is the most competent way of reducing the ever growing traffic congestion of the developing city. Mass transit has the advantage of smaller rights of way and developing lesser amount of infrastructure required for highways and roads

The amount of space required to transport the same number of passengers: car, bicycle, and bus.

All public transport or mass transit system runs on infrastructure, either on roads, rail, airways or seaways.

Types of Mass Transit Systems include:

1. MRT (Mass Rapid Transit)
2. LRT (Light Rail Transit)
3. BRT (Bus Rapid Transit)
4. Metros
5. Commuter Rails

Between heavy rails and light rails, heavy rails are one of the better forms of mass transit as they are fast and will not interfere with the other traffic as they require separate underground infrastructure. But the initial cost of heavy rail is very high. It works best at places where a larger number of people will ride them such as in the center of big and densely populated citie

Impacts - Advantages of Mass Transit:

Environmental Impacts

Mass transit system is believed to be more environmental friendly than other public transport facilities. Private vehicles emit about twice as much carbon monoxide and other volatile organic compounds than public vehicles. Mass transit reduces the number of cars on the road which in turn reduces the pollution caused by individual cars. Mass transit systems also take up much less space than do the highways needed for the movement of automobile traffic.

In terms of air quality the crucial factor in developing cities is not so much the emission performance of the different MRT modes, but rather their potential in getting people out of cars and off motorcycles, and into transit. To the extent that a BRT system can do this better than a rail system (with much more limited coverage), BRT has a greater positive environmental impact.

Social Impacts of Mass Transit System

All members of the society irrespective of their financial status, religion or cast are able to travel which enhances the social integrity of the country. The necessity of a driving license is also eliminated. It is a blessing for those individuals who are unable to drive.

Mass Rapid Transit plays an important role in alleviating poverty or increasing the standard of living of the poor. It is the poorest people who most depend upon public transit for access to jobs and services. In some cities the urban poor pay up to 30% of their income on transport. The poor also typically live in lower rent areas on the outskirts of the city and in some cases spend two to four hours commuting each day.

Demand – Supply - System are the three dimensional frames which configure the directional growth of urbanization. An ideal supply system must be configured to meet the travel demand and incorporate the change of land use and socio – economic characteristics. The spatial configuration of the key elements of the supply system (nodes, links, paths, network) act as transitional fabric / surface for disseminating and shaping the demand profiles over time and space. These transitional entities are often dynamic in nature and are constantly subjected to the change in functionality due to the process of urbanization. The non-systematic planning and orientation of the spatial configuration of these entities makes the system to be non-functional and non-hierarchical posing a low operational performance of the supply system. Non-uniform spread of demand over the supply system due to the dynamics involved in the user preferences, trip lengths, trip orientations and existing undefined hierarchy and functionality of the supply system leads to under utilization of the supply system and non-uniform demand responsive system. Moreover, constant changes in demand created an imbalance in land use and system characteristics and vice versa. It is difficult to control the dynamics of user preferences, trip lengths and orientations as it involves stringent urban policy decisions to the immediate effect. But hierarchy of the supply system can be defined and controlled by properly spreading the transitional entities uniformly. This strategy would give a lead in controlling the user preferences, trip lengths and orientations over a time frame. This strategy inherently develops a touch stone principle to make demand and supply in equilibrium by development of fractal / self similar transitional fabric to disseminate the demand and deconcentrate it over time and space. The planning can be done if the supply system is assumed as merely a system with no defined hierarchy and treating the nodes and links as equal demand transfer points. The user preferences are then imposed on the supply system to emerge a hierarchical system of paths and links. Similarly nodes can also be made hierarchical over a space which decentralizes the demand and maximizes the access to the area. This hierarchical system shall be oriented to develop a fractal system. When demand and supply weigh uniformly in the equilibrium condition and start exceeding the breakeven point leading to uneconomic travel, risk generation and poor environment conditions, transportation system coordination with demand and supply can be formulated.

1. Problem description

This case study illustrates the economic appraisal of a proposal to develop a new fixed track facility such as a train or LRT line or a busway with a dedicated right of way. The new facility will be in a corridor currently served by on-street bus services. The case study illustrates the range of cost and benefits that should be considered, the basis for each category of cost and benefit, and the interpretation of the data on costs and benefits.

2. Options

A single Project Case option is considered relative to the Base Case.

The Project Case option was identified in prior assessment as having high potential of strategic alignment and rapid appraisal of a number of options. Other high potential options can also be appraised in a similar manner to the option considered here.

Base Case

Option 0: Do minimum: The Base Case is a 'do minimum' option in which the quality of on-street bus service in the first year of the appraisal period is maintained. Even with a small amount of bus priority that could be implemented, this requires additional buses (and associated bus-hours and bus-km of service) to accommodate modest growth in patronage associated with rising population and to respond to increasing traffic congestion that will reduce average bus travel speed. There are no opportunities for an alternate scheme with somewhat more substantial investment that could provide a reasonable alternative Base Case.

Project Case options

Option 1: New fixed track facility (train, LRT or busway)

3. Benefits and costs

Table 1 lists the benefits and costs and whether they have been monetised in this worked example.

The initiative is expected to lead to the following impacts (all incremental from the Base Case to the Project Case):

- Ongoing costs for maintenance of the fixed infrastructure and for changes in the cost of providing public transport service
- Reduced travel time for existing public transport users and those that shift from cars to public transport
- Reduced travel time for remaining road users due to the mode shift from car to public transport, and the shift of public transport services from on-road operation to its own right-of-way
- A reduced need for car ownership and car parking due to the shift of some former car drives to public transport
- Reduced road crashes and environmental costs due to reduced car use from the shift to public transport after also allowing for crash costs and environmental costs that result from providing a larger quantity of public transport

- Some disruption to road traffic during construction of the initiative.

Travel time disbenefits may be incurred by cars, trucks and remaining on-road buses due to reduced lanes or space availability if the new fixed track or facility is integrated into the existing road layout without expanding or widening. If this impact applied, it would flow through to the cost-benefit analysis as a monetised disbenefits to non-public transport users.

Table 1 Monetised and non-monetised benefits and costs

	Monetised	Non-monetised
Benefits		
Travel time savings for public transport users	✔	
Travel, car and parking savings for car users who shift to public transport	✔	
Travel time savings for remaining road users	✔	
Safety and environmental benefits	✔	
Residual value	✔	
Disruption during construction (disbenefit)	✔	
Costs		
Fixed infrastructure costs	✔	
Operating and maintenance costs	✔	

4. Inputs and assumptions

4.1 General

Base year and price year: Prices are in mid-2014 prices and are discounted to a base year of 2015.

Real discount rate: 7% for the main central analysis, with sensitivity tests of 4% and 10%.

Construction period years: 4 years – 2016 to 2019.

Operations to commence in 2020.

Investment cost:

All costs in the appraisal are incremental to the Base Case – practitioners are encouraged to also show Base Case and Project Case numbers used to calculate the incremental change between the two cases:

- Fixed infrastructure: $635 million
- Public transport fleet: $95m in 2019, and a total of $121m during the remainder of the appraisal period (some of which are reinvestments as discussed below)
- Land (resale of excess land): minus $28m in 2020.

Fixed assets

The initiative involves expenditure on land and fixed infrastructure such as earthworks, track, stations, power and other control systems as needed. It also requires design and project management services.

The initiative requires the purchase of some large allotments of land due to the shape of the allotments and a need for some space to accommodate site offices and construction equipment. Much of this land can be sold at a premium upon completion of the construction when it is no longer needed and has higher value due to its proximity to public transport stations. Hence, there is a large negative cost in the year that follows completion of capital works (2020).

Public transport fleet

An initial fleet of new public transport vehicles is to be purchased for the initiative. (If the initiative was a busway, a new fleet of dedicated buses would be purchased, with none of the on-street buses used to provide services in the corridor being suitable for use on the busway.) This fleet is purchased in the year prior to initiative completion (2019). It is estimated that fewer of the current on-street buses will be needed in the corridor with the initiative, with account for the remaining value of the redundant buses included in the appraisal – the buses can be used elsewhere in the public transport system, and the avoided cost attributed to the current initiative is therefore based on the residual value of the buses. There will also be an avoided need in the Project Case to purchase additional buses that would have been needed to accommodate small rising patronage in the corridor in the absence of the initiative.

Over the appraisal period there is an occasional need to purchase additional vehicles for the new facility to accommodate growth in patronage and to replace vehicles that may reach the end of their economic life during the appraisal period (though the latter will generally only occur in the case of a busway). Hence, additional capital costs are incurred following initial implementation of the initiative.

WHAT IS MRTS?

- *Mass rapid transit, also referred to as public transit, is a passenger transportation service, usually local in scope, that is available to any person who pays a prescribed fare.*

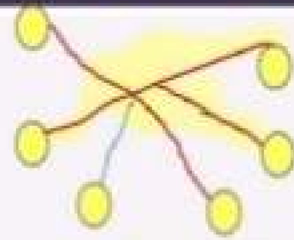
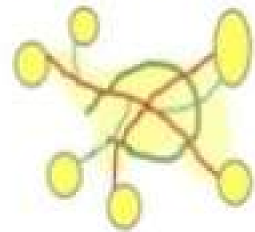
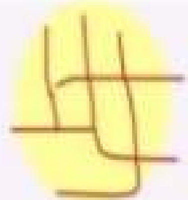
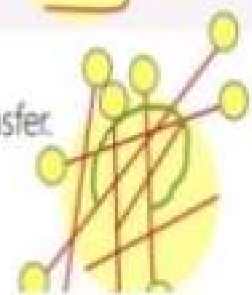
- *It usually operates on specific fixed tracks or with separated and exclusive use of potential common track, according to established schedules along designated routes or lines with specific stops.*

- *It is designed to move large numbers of people at one time.*

HISTORY

- *The world's first mass rapid transit system was the partially underground Metropolitan Railway which opened as a conventional railway in 1863,and now forms a part of the London Underground.*
- *The first BRT system in the world was the OC Transportation system in Ottawa, Canada.*
- *Among the operational ones, the first monorail transit system was started in Wuppertal and Dresden in Germany in the year 1901.*
- *1984 - The first rapid transit system in India was the Kolkata Metro*
- *2006 - Pune was the first city in India to experiment with a Bus Rapid Transit system*
- *2014 -The Mumbai Monorail, which opened on 2 February 2014 is the first operational monorail in India*

TYPES OF MRTS NETWORKS

S.no.	Type	Description	
1.	Radial Networks (with or without branches)	• In cities with strong emphasis on the centre. • Lines follow major travel directions. • Does not cater to non-CBD oriented trips. • Lines majorly overlap giving less coverage.	
2.	Radial Circumferential Networks	• Consists of Radial, Diametrical, ring lines. • Typically serves busy corridors and many sub-centres. • Intersection creates transfer points and covers non-CBD trips as well. • Have greater coverage.	
3.	Rectangular / Grid Networks	• Transit lines follow geometric pattern. • Cities with uniform density. • Provides uniform coverage.	
4.	Ubiquitous Networks	• Service in all high demand corridors. • Good connectivity amongst transit lines requiring maximum one transfer. • Adequate coverage throughout the urban area. • Good connections to non-CBD oriented trips as well.	

TYPES OF MRTS


Bus Rapid Transit System


Metro Rail Transit System


Mono-Rail Transit System


Light Rail Transit System

- *Bus Rapid Transit is a form of customer orientated transit combining stations, vehicles, planning, and intelligent transport systems elements into an integrated system with a unique identity.*

- *Bus Rapid Transit typically involves bus-way corridors on segregated lanes–either at-grade or grade separated and modernised bus technology. However, apart from segregated bus ways,*

EXPRESS BUS SERVICE

Description

Express bus service is a type of fixed route that typically picks up passengers from park-and-ride lots in suburban areas and takes them to a central urban location. This transit service usually operates for longer-distance trips on a Monday through Friday, peak commuter time schedule. These commuter routes have limited stops, typically travel non-stop on highways (utilizing any available HOV lanes), and terminate at the central business district in the city. Fares for the service may be comparable to park-and-ride fares, slightly higher than typical local fixed route service.

Target Market

Longer-Distance Commuters

Commuters from suburban areas, including state employees, students, and employees working in the central city are viable users of this service. Typically, commuters who would otherwise utilize freeways to travel to and from work during the week serve as potential users, because this service can use HOV lanes and create a less-stressful commute.

How Will This Help?

- Increased transit usage can reduce the number of single occupancy vehicles on major freeways and highways. This decreases the traffic demand on the major urban freeways and streets.
- Express service can serve as an alternative to personal automobiles. Suburban commuters can depend on this transit service to commute to the urban central business district.
- Passengers can improve their time management by working on the bus, which is typically equipped with Wi-Fi services. Commuters can have more time to handle personal and business matters, rather than wasting time on a congested freeway.

Cost:	●●●○○
Time:	**Moderate**
Impact:	**Corridor**
Who:	**Transit Provider**
Hurdles:	**Competitiveness, Funding & Sustainability**

Implementation Examples

Houston—Houston Metro offers express bus service from 29 park-and-ride facilities throughout the metroplex. In Houston, the express services have direct access to the HOV network throughout the city, making express bus service a competitive alternative to the personal automobile. One example of a successful service in Houston is the Fort Bend Express. The express provides weekday commuter service to the Texas Medical Center, with connections to fixed route services on the medical center campus.

Austin—Capital Metropolitan Transportation Authority (CMTA) developed express bus service on Highway 183 utilizing a church parking lot as an interim park-and-ride location until demand grew enough to warrant the construction of a new facility. The new facility, Lakeline Station, opened in 2006, and ridership has increased steadily, offering express service from Northwest Austin to downtown, as well as local bus connections, and MetroRail service. Usage increased from fewer than 200 vehicles at the station opening in 2006 to greater than 400 vehicles utilizing the park-and-ride in 2011 and is expected to continue growing.

Application Techniques and Principles

Agencies should keep land uses, customer origins, and destinations in mind when planning express routes. Morning express lines typically originate in suburban areas from major stations and park-and-rides outside of the major congestion points on corridors. Central business districts and major employment and commercial centers are ideal destinations for express routing.

Express routes operate differently than standard fixed route buses, meaning some different service requirements:

- Require activity center (transit station or stop) floor space of at least 20-50 million square feet to support service.
- Express bus reached by walking requires:
    - Minimum of 15 dwelling units per acre over two square miles of collection area for five trips during the two-hour peak period.
    - Trips originate 10 to 15 miles from largest downtown
- Express bus reached by automobile requires:
    - Minimum of three dwelling units per acre over 20 square miles of collection area for 5 to 10 bus trips during the two-hour peak periods.
    - Trips originate 10 to 20 miles from downtown.

Issues

Express commuter services require careful planning, especially in areas of high transit demand during peak periods. Vehicle size should be taken into consideration during planning; larger vehicles should be assigned to the routes with the highest demand. Route frequencies can be adjusted as ridership on express routes increases. Buses arriving as frequently as five minutes, for example, may be necessary at some locations.

Adequate planning is the most important thing to consider when implementing an express bus route. Planners should survey the potential users to determine schedules and routing, and should typically offer service in conjunction with one or more park-and-rides. In areas with limited ridership, sustainability can be an issue, so it is critical to market and promote the service accordingly. It is also important for these types of routes to have access to HOV/HOT or managed lanes. Express route travel times should be competitive to driving a personal vehicle so they can be a viable solution to mitigate congestion.

Who Is Responsible?

The local transit provider is responsible for planning and implementing express route services. This agency may be a transit authority, transit district, the city or local government, or the metropolitan planning organization, depending on the location. Routes, stops, and park-and-rides should be planned and coordinated in conjunction with local stakeholders that may be affected.

Project Timeframe

The timeframe may vary as it depends on the level of service required. Route planning and implementation usually lasts six to nine months but can take at least a year. The following steps are typically required in the process.

Proposal Development

- Service analysis—determine whether express bus service is needed or would be a good fit for the area.
- Initial concepts—provide basic schematics on proposed routing and scheduling.
- Review of customer and operator input—review customer and operator comments to determine if there has been demand in a specific area for express level service.
- Concept refinement and cost estimates—based on the comments, refine the design and schedules; develop costs for service based on hours of service needed to run route.
- Title VI and ADA review—recommended for most new services. Note that express routes do not require complementary paratransit.
- Initial proposals—vetting of proposed route(s) and schedule(s) with internal stakeholders (marketing, scheduling, and operations).
- Community outreach (riders, general public, advisory committees, etc.)—take proposals to advisory groups and targeted populations the route(s) would serve to gather feedback.
- Public meetings—hold meetings in central locations accessible by public transit to gather additional feedback.
- Proposal revisions—revise proposals based on all information gathered.

Board Process

- Board committee review—present initial proposals and community feedback received to board work session or board planning committee.
- Public hearing—hold separate public hearing for last-round of comments.
- Final recommendations—present final proposal and recommendations for service to transit board of directors.
- Board decision—transit board of directors approves or disapproves service.

Implementation Preparation

- Schedule development—if service is approved, schedules are tested and finalized.
- Operator work assignments—route is presented for operator bidding at the next work assignment period.
- Marketing and communication materials—development and distribution of marketing and communications materials advertising the service offered.
- Capital upgrades (vehicles, facilities, stops, etc.)—development and building of accessible stops, benches, shelters, and stations associated with the route. Purchase of new vehicles, if needed.
- Information technology updates—updates and upgrades to agency website, automatic vehicle location (if applicable), and operator schedule sheets.

Cost

Implementation and planning costs can vary depending on the planned level of service. Fixed routes in an urban area can typically cost approximately $100/hour. The cost is affected by the route features, including hours of service and route mileage. Fare box recovery is typically nominal and not necessarily taken into consideration for route funding purposes.

Data Needs

Planners should collect demographic and regional data prior to route planning. Data collection involves origin and destination surveys, mapping of major employment centers, and service attractors.

Express Bus Service Best Practice

- Type of Location: Express bus service is best implemented in suburban areas that have heavy commuter traffic to a central business district or a group of major employers in a central location.
- Agency Practices: Facilities that support parking; ability to access the station or park and ride with a neighborhood shuttle, kiss and rides, bicycle and pedestrian modes.
- Frequency of Reanalysis: Initial analysis every three to four months to determine potential adjustments to routing and schedules; may be re-examined every six months to a year after once route is mature.
- Complementary Strategies: Park-and-ride implementation, bus on shoulder, and express (managed) lanes.

For More Information and References

1. Transit Cooperative Research Program. Transit Capacity and Quality of Service Manual, 2nd Edition. Washington, D.C., 2003.

2. Transit Cooperative Research Program. TCRP Report 95, Chapter 10: Bus Routing and Coverage. Washington, D.C., 2004.

Terminal Facilities means all terminal facilities and spaces leased, subleased or otherwise retained or used by a party at an Applicable Airport, including without limitation all passenger lounges, passenger holding areas, aircraft parking positions (which may or may not be adjacent to a passenger holding area) and associated ramp spaces, gates (including loading bridges and associated ground equipment parking areas), ticketing counters, curbside check-in facilities, baggage makeup areas, inbound baggage areas, crew rooms, in-terminal office spaces, associated employee parking areas and other terminal facilities.

A **transfer** allows the rider of a public transportation vehicle who pays for a single-trip fare to continue the trip on another bus or train.[1] Depending on the network, there may or may not be an additional fee for the transfer.[2] Historically, transfers may have been stamped or hole-punched with the time, date, and direction of travel to prevent their use for a return trip. More recently, magnetic or barcoded tickets may be recorded (as on international flights) or ticket barriers may only charge on entry and exit to a larger system (as on modern underground rail networks).

OBJECTIVES OF HIGHWAY PLANNING-

1. A highway should be plan according to the volume of daily traffic flow from a particular path. For this purpose proper survey must be done to collect the adequate amount of data.
2. The highways develop must be efficient, but at a minimum cost, especially in cases of developing and underdeveloped countries.
3. The highways should be safe and secure.
4. The planning must have a forecast for next several years in order plan fix periods for maintenance, renewal and widening as well.

Roads in Ancient India

- Mohenjo-daro and Harappa

Roads in Mughal Period

- Roads in 19th Century
- 1865 Lord Dalhousie, formed the Public Works Department – Grand Trunk Road

Jayakar Committee & the Recommendations (1928)

- Road development considered as a national interest
- Extra tax levied on petrol from road user
- Semi official technical body formed
- Research organization should be instituted

(CRF - 1929, IRC – 1934, CRRI- 1950)

CRF (1929)

- Consumer of petrol were charged an extra levy of 2.64paisa per liter per gallon
- 20 % of annual revenue retained as central reserve
- 80 % allotted by the central govt to various states
- CRF maintained by Accountant General of Central Revenue
- Control on the expenditure Road Wings of Ministry of Transport
- CRF Act – 2000, rate of duty on petrol & High speed diesel – 2 rupee per liter

IRC (1934)

- To provide pooling of experience & idea on planning, construction & maintenance of roads
- Active body of controlling specifications, standardization, & recommendations on material, design & construction of roads & bridges
- Technical activity carried by HRB & committees & sub committees

Motor Vehicle Act (1939)

- To regulate the road traffic in the form of traffic laws, ordinances & regulations
- Control of the driver, vehicle ownership, & vehicle operation
- Revised 1988

Nagpur Road Conference (1943)

- First road development plan (Nagpur Road) 1943-1963
- The target road length 16 km per 100 square km area of the country
- Achieved in 1961

CRRI (1950)

- It is one of the national laboratories of the council of scientific & industrial research
- Applied research offered advice to state govt & industries

National Highway Act (1956)

- Maintenance of NH taken by Central govt
- Central govt empowered to declare any other highway as NH & omit existing NH from list

Second 20 Yr Road Development Plan (1961-1981)

- Bombay road Plan
- Target road length of 10,57,330 km or about 32 km per hundred sq km area
- Rs. 5200 crores for 1980-81 was envisaged for this plan based on 1958 price level
- 1600 km of Express ways included
- Total length of all category roads achieved by 1974 – 11.45 lakhs km, road density – 34.8 km per 100 sq.km area

Earthen Roads

Earthen roads are laid with soil. They are cheaper of all types of roads. This type of road is provided for less traffic areas and or for countryside areas. Good drainage system should be required which reflects good performance for longer period.

Gravel Roads

Gravel roads are also low quality roads but they are good when compared to earthen roads. Compacted mixture of gravel and earth is used as pavement material in this case.

Murrum Roads

Murrum is a matter obtained from the disintegration of igneous rocks by weathering agencies. This is used to make roads called as murrum roads.

Kankar Roads

Kankar is nothing but impure form of lime stone. Kankar roads are provided where lime is available in good quantity. These are also low quality and performance wise they are similar to gravel and murrum roads.

WBM Roads

Water Bound Macadam (WBM) roads contain crushed stone aggregate in its base course. The aggregates are spread on the surface and these are rolled after sprinkling water.

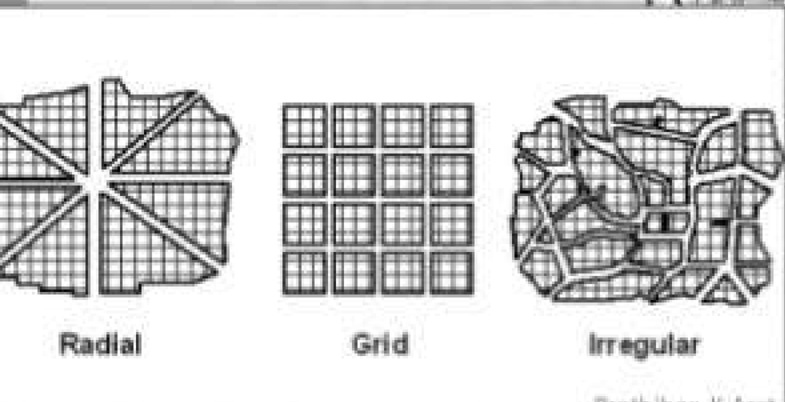
WBM roads provides better performance compared to earthen, gravel, murrum and kankar roads.

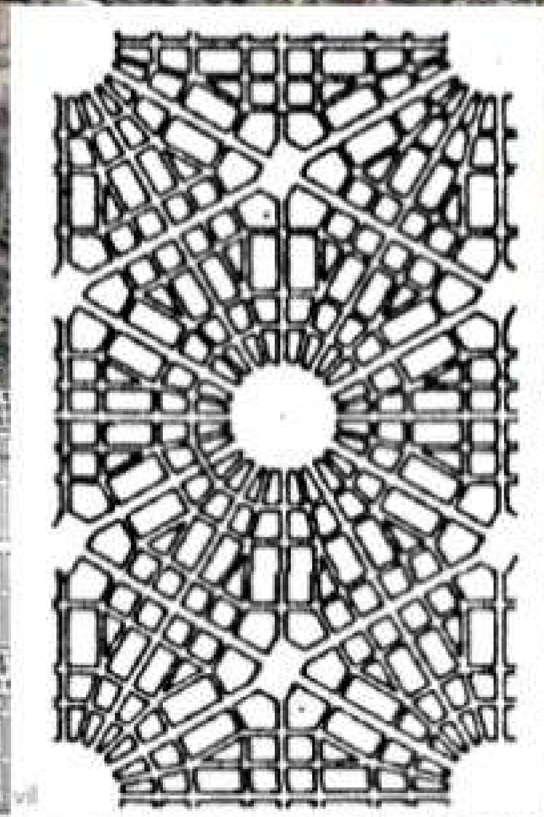
WBM roads are laid as layers about 10cm thickness of each layer. They are very rough and may disintegrate immediately under traffic.

Road pattern

The various road pattern may be classified as follows

- Rectangular/ block pattern
- Radial / star & block pattern
- Radial / star & circular pattern
- Radial / star & grid pattern
- Hexagonal pattern
- Minimum travel pattern





William Penn's plan of the City of Philadelphia. The idea of straight streets and recta
without curves or diagonals has been carried out in the enlarged city, while the system o

Radial or Star and Circular Pattern:

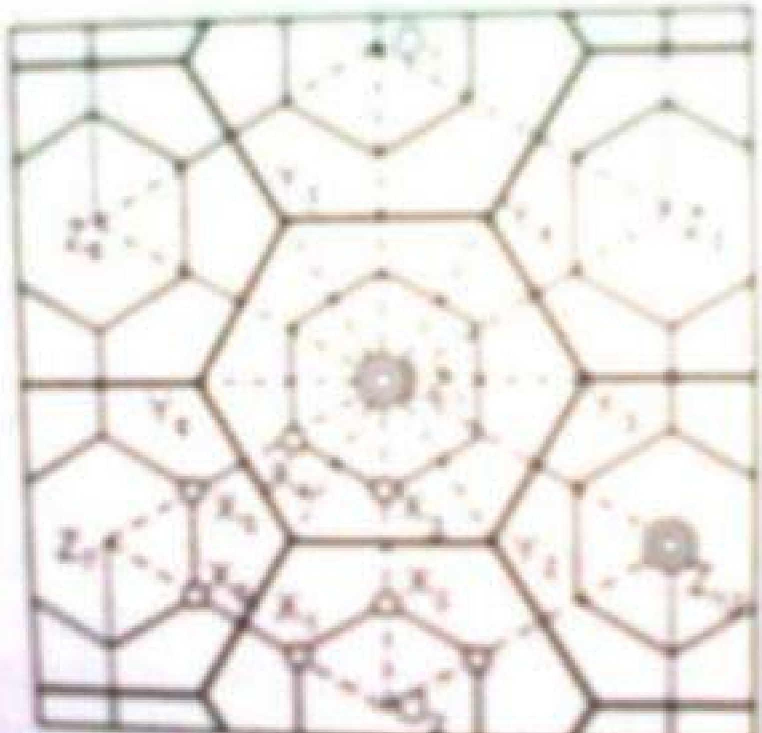
Advantage:

1) At traditional intersections with stop signs or traffic signals, some of the most common types of crashes are right-angle, left-turn, and head-on collisions.

should extend far enough to provide pedestrian refuge and to delineate the roundabout.

Hexagonal Pattern :

Minimum Travel Pattern



Engineering Surveys for Highway locations

Before a highway alignment is finalised in highway project, the engineering survey are to be carried out. The various stages of engineering surveys are

- Map study (Provisional alignment Identification)
- Reconnaissance survey
- Preliminary survey
- Final location and detailed surveys

MAP STUDY

- From the map alternative routes can be suggested in the office, if the topographic map of that area is available.
- The probable alignment can be located on the map from the fallowing details available on the map.
  - Avoiding valleys, ponds or lake
  - Avoiding bend of river
  - If road has to cross a row of hills, possibility of crossing through mountain pass.
- Map study gives a rough guidance of the routes to be further surveyed in the field

RECONNAISSANCE SURVEY

- To confirm features indicated on map.
- To examine the general character of the area in field for deciding the most feasible routes for detailed studies.
- A survey party may inspect along the proposed alternative routes of the map in the field with very simple instrument like abney level, tangent clinometer, barometer etc.... To collect additional details.
- Details to be collected from alternative routes during this survey are,
  - Valleys, ponds, lakes, marshy land, hill, permanent structure and other obstruction.
  - Value of gradient, length of gradient and radius of curve.

Preliminary survey

Objective of preliminary survey are:

- To survey the various alternative alignments proposed after the reconnaissance and to collect all the necessary physical information and detail of topography, drainage and soil.
- To compare the different proposals in view of the requirements of the good alignment.
- To estimate quantity of earthwork materials and other construction aspect and to workout the cost of the alternate proposals.

Methods of preliminary survey:

a) **Conventional approach**-survey party carries out surveys using the required field equipment, taking measurement, collecting topographical and other data and carrying out soil survey.

Final location and detailed survey

- The alignment finalised at the design office after the preliminary survey is to be first located on the field by establishing the centre line.

Location survey:

- Transferring the alignment on to ground.
- This is done by transit theodolite.
- Major and minor control points are established on the ground and centre pegs are driven, checking the geometric design requirements.
- Centre line stacks are driven at suitable intervals, say 50m interval in plane and rolling terrains and 20m in hilly terrain.

Drawing and Report

- Key map
- Index map
- Preliminary survey plans
- Detailed plan and longitudinal section
- Detailed cross section
- Land acquisition plans
- Drawings of cross drainage and other retaining structures
- Drawings of road intersections
- Land plans showing quarries etc

Roadway Construction

- Carriageway
- Pavement
- Kerb
- Shoulder
- Sidewalks / Footpath

Carriageway

Kerb

Shoulder

Sidewalks/Footpaths

Equipment:

- Compacting material (vibratory roller)
- Dozer and scraper
- Power shover, shovels
- Concrete mixer
- Watering devices
- Mild steel sections and blocks
- Barricading
- Signage board

BITUMEN ROAD CONSTRUCTION PROCEDURE

1. Preparation of the existing base course layer

The existing surface is prepared by removing the pot holes or rust if any. The irregularities are filled in with premix chippings at least a week before laying surface course.

2. Application of Tack Coat

It is desirable to lay AC layer over a bituminous base or binder course. A tack coat of bitumen is applied at 6.0 to 7.5 kg per 10 sq.m area, this quantity may be increased to 7.5 to 10 kg for non-bituminous base.

3. Preparation and placing of Premix

The premix is prepared in a hot mix plant of a required capacity with the desired quality control. The bitumen may be heated upto 150 – 177 deg C and the aggregate temperature should not differ by over 14 deg C from the binder temperature. The hot mixed material is collected from the mixture by the transporters, carried to the location is spread by a mechanical paver at a temperature of 121 to 163 deg C. the camber and the thickness of the layer are accurately verified.

4. Rolling

A mix after it is placed on the base course is thoroughly compacted by rolling at a speed not more than 5km per hour.

The initial or break down rolling is done by 8 to 12 tonnes roller and the intermediate rolling is done with a fixed wheel pneumatic roller of 15 to 30 tonnes having a tyre pressure of 7kg per sq.cm. the wheels of the roller are kept damp with water. The final rolling or finishing is done by 8 to 10 tonne tandem roller.

5. Quality control of bituminous concrete construction

The routine checks are carried out at site to ensure the quality of the resulting pavement mixture and the pavement surface.

Right of Way

- The right of way can be described generally as the publicly owned area of land that encompasses all the various cross-section elements.
- The right of way is the land set aside for use as a highway corridor.
- Rights of way are purchased prior to the construction of a new road, and usually enough extra land is purchased.
- Sometimes, rights of way are left vacant after the initial roadway facility is constructed to allow for future highway expansion.

Right of Way

Requirements of area for right of way are as follows:

- For 2 lane road = 150 ft width of area
- For 4 lane road = 250 ft width of area
- For 8 lane road = 300 ft width of area

A **gravel road** is a type of unpaved road surfaced with gravel that has been brought to the site from a quarry or stream bed. They are common in less-developed nations, and also in the rural areas of developed nations such as Canada and the United States. In New Zealand, and other Commonwealth countries, they may be known as metal roads.[1][2] They may be referred to as "dirt roads" in common speech, but that term is used more for unimproved roads with no surface material added. If well constructed and maintained, a gravel road is an all-weather road.

Construction Procedure for Earthen Road

- Preparation of Sub-Grade: Arranging sub-grade in proper gradient & camber.
- The sub-grade is rolled & watered to have OMC & compacted to MDD.
- Over it, a layer of soil 10cm thick is sprayed, rolled, & finished to have required camber & gradient.
- 4-5 days curing.
- Opening to traffic.
- Watering for 10 days after opening to traffic.

WBM Roads

Definition: The pavement base course made of crushed or broken aggregates mechanically interlocked by rolling and voids filled by screening and binding material with the assistance of water

Salient Features of WBM Roads

- WBM means Water Bound Macadam.
- The word Macadam comes from the name of Scottish Engineer John L. Macadam.
- Wearing surface is formed by cleaned, crushed aggregates which are spread and rolled by sprinkling water.

5.4 WET MIX MACADAM

The construction of Wet Mix Macadam (WMM) consists of laying and compacting clean, crushed, and graded aggregates, premixed with water. WMM is prepared in a mixing plant, in which aggregates and water with suitable proportion are mixed together.

The optimum moisture content of the mix is determined in the laboratory. The aggregates, immediately after mixing, are laid on the surface.

After the completion of the construction, setting time is given, during which it is desirable that not even construction equipment should pass over the surface.

A road is a thoroughfare, route, or way on land between two places, which has been paved or otherwise improved to allow travel by some conveyance, including a horse, cart, or motor vehicle. Roads consist of one, or sometimes two, roadways (carriageways) each with one or more lanes and also any associated sidewalks (British English: pavement) and road verges. Roads that are available for use by the public may be referred to as public roads or highways.

Everyone is aware about the benefits and advantages of a good constructed road. Roads play very crucial role in modern society providing services and goods for modern people. Today a vast majority of road are constructed using Asphalt. Now question arises in your mind is "What is Asphalt"? Asphalt is the sticky dark brown viscous liquid present in some natural deposits like crude petroleum. It is the name given to technically or natural mixture used in road construction for road surfacing and compaction.

We see many roads daily and when we talk about the road construction, all are equally constructed but there is a difference arising in the finishing of the road or the surface material used for finishing. Asphalt, also known as bitumen concrete in engineering language is used to give flexible surface to roads. Asphalt road offers many benefits such as smooth and flexible surface including cost efficiency, improved safety and comfort, durability, recyclability and reduction in noise pollution. Sometimes Asphalt or bitumen are confused with tar. Although they are same in color, they have distinct chemical properties. Tar was early used in road Asphalt, but now has been replaced by refined bitumen or Asphalt. Today Asphalt is more commonly produced as a byproduct of the refining process in the petroleum industry.

Road construction is not as easy as it seems to be, it includes various steps and it starts with its designing and structure including the traffic volume consideration. Then base layer is done by bulldozers and levelers and after base surface coating has to be done. For giving road a smooth surface with flexibility, Asphalt concrete is used. Asphalt requires an aggregate sub base material layer, and then a base layer to be put into first place. Asphalt road construction is formulated to support the heavy traffic load and climatic conditions. It is 100% recyclable and saving non renewable natural resources.

With the advancement of technology, Asphalt technology gives assurance about the good drainage system and with skid resistance it can be used where safety is necessary such as outside the schools.

The rigid characteristic of the pavement are associated with rigidity or flexural strength or slab action so the load is distributed over a wide area of subgrade soil. Rigid pavement is laid in slabs with steel reinforcement.

1.The rigid pavements are made of cement concrete either plan, reinforced or prestressed concrete.

2.Critical condition of stress in the rigid pavement is the maximum flexural stress occurring in the slab due to wheel load and the temperature changes.

3.Rigid pavement is designed and analyzed by using the elastic theory.

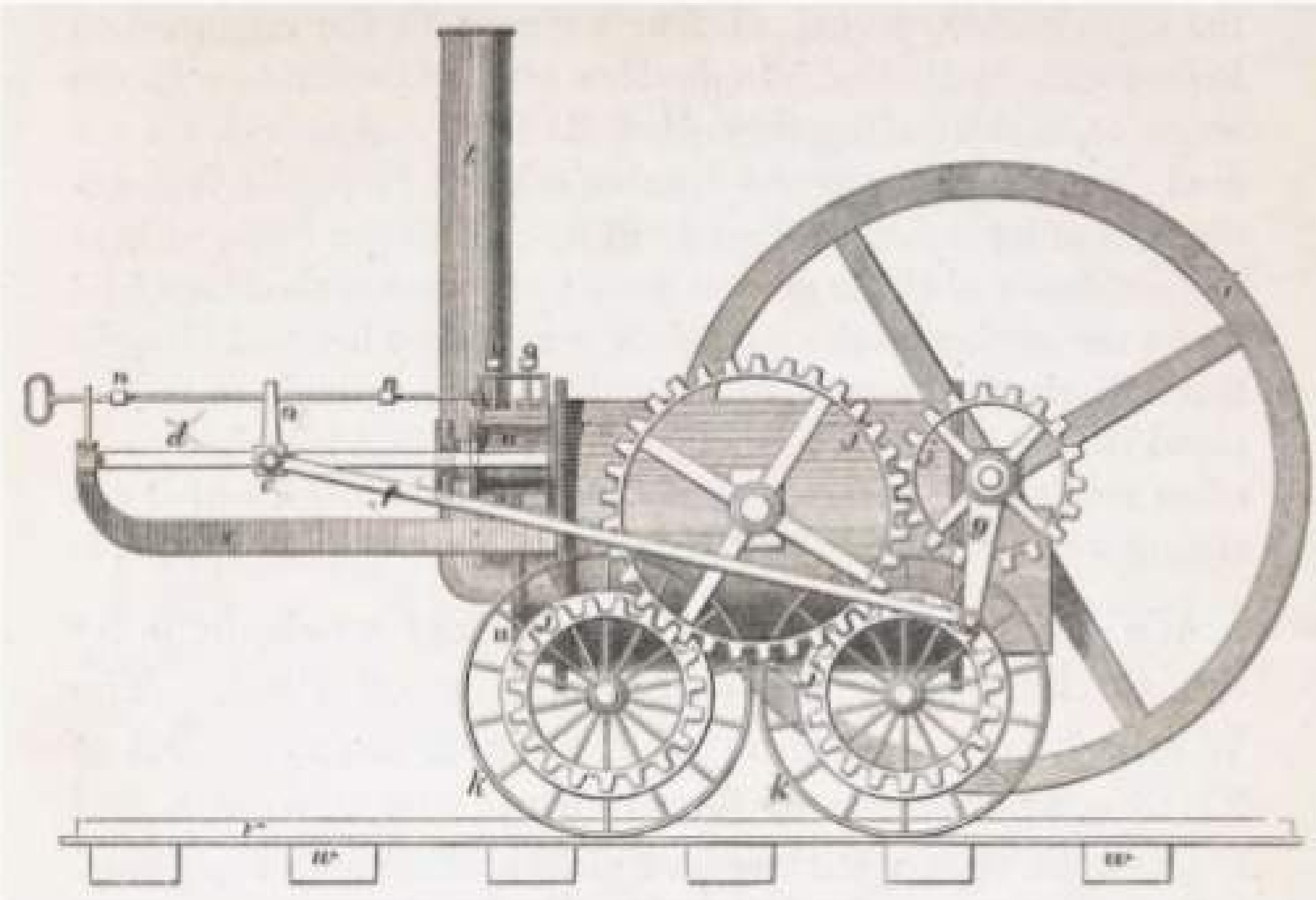
Advantages of Rigid Pavement

1. Rigid lasts much, much longer i.e 30+ years compared to 5-10 years of flexible pavements.
2. In the long run it is about half the cost to install and maintain. But the initial costs are somewhat high.
3. Rigid pavement has the ability to bridge small imperfections in the subgrade.
4. Less Maintenance cost and Continuous Traffic and Flow.
5. High efficiency in terms of functionality

History of Railways

In India first railway was built between Mumbai and Thane in 1852 and the first passenger train ran between the two stations, covering a distance of 34 km, on April 16, 1853.

BLUE PRINT OF FIRST TRAIN



FIRST TRAIN RUN IN INDIA

- 3:35pm on April 16th, 1853
- a train with 14 railway carriages and 400 guests left Bombay's Bori Bunder for Thane, with a 21-gun salute.
- It was hauled by three locomotives: Sindh, Sultan, and Sahib.
- The journey took an hour and fifteen minutes.

CHRONOLOGY OF RAILWAYS IN INDIA

1832

- First proposal for a railway in India, in Madras. This remained a dream on paper.

1835-1836

- A short experimental railway line is constructed at Chintadripet, near Madras, which later became the Red Hill Railroad.

1837

- The first operational railway in India - the Red Hill Railroad near Madras, used for transporting granite stone.

1838

- Likely date of first locomotive built in India.

1840s

- Various proposals for railways in India, especially around Calcutta (EIR) and Bombay (GIPR).

1844

- R MacDonald Stephenson's "Report upon the Practicability and Advantages of the Introduction of Railways into British India" is published.

1845

- A railway is in operation near Rajahmundry for conveying construction material and stone for irrigation works and a dam across the Godavari.
- Survey work carried out for Bombay-Kalyan line and an extension up the Malay Ghat for proposed connections to Khandwa and Pune.
- May 8: Madras Railway Company is formed.
- East India Railway company is formed.

1849

- August 1: Great Indian Peninsular Railway incorporated by an Act of Parliament..

1851

- Construction begins of an "experimental" section of track (Howrah-Rajmahal) for the proposed Calcutta-Delhi link via Mirzapur (EIR).

1852

- Construction of a line out of Bombay begins, and a locomotive, *Falkland*, begins shunting operations on February 23. The line is ready by November, and on the 18th of November, a trial run of the Bombay-Thane trip (35 km) is held.
- The Madras Guaranteed Railway Company is formed.

1853

- On April 16th, at 3:35pm, the first train in India leaves Bombay for Thane.
- Madras Railway incorporated; work begins on Madras-Arcot line.
- Lord Dalhousie's famous Railway Minute of April 20 lays down the policy that private enterprise would be allowed to build railways in India, but that their operation would be closely supervised by the government.

1854

- On August 15th, the first passenger train in the eastern section is operated, from Howrah to Hoogly (24 miles). The section is soon extended to Pundooah.
- GIPR opens its first workshops at Byculla.
- Stations are classified into 4 groups on some railways, according to traffic and the proportion of European and Indian passengers.

Challenges faced by Indian Railways

- **Overcrowding, low frequency** and **lack of universal design**
- **Lack of financial resources**
- **Low per-capita income** : 23 percent of Indian urban population living in poverty
- **Extremely low fares :** Due to 70% (as per the Census 2011) of Indian population living in rural area
- **Misuse of Coach for Disabled**

Reason for Increase in Demand

- **Growing Population**: Increased in urban population from 62 million in 1951 to 285 million in 2001 and is estimated to be around 540 million by the year 2021
- **Extension of cities far beyond old city boundaries**
- **Increased Urban trips** : 80 million trips will need to be catered per day, whereas only 37 million trips are being provided by the available rail and bus mass transport facilities
- **Scattered residential and commercial development without necessary infrastructure**

- The Indian Railways have provided a separate compartment for the disabled passengers at the end of the train next to the guard van.

- The attempts have been made by Indian Railways to incorporate the accessibility features at some of the railway stations (like Delhi railway station and Agra Cantt railway station) such as earmarked parking for the wheelchair users, accessible entrance, waiting room with accessible toilet and above all inter connectivity of all the platforms with the ramp.

Accessible Features at Railway Station, New Delhi

Ramp at the entrance

Accessible toilet at the platform

Drinking Water counters at two levels

Placement of tactile warning and guiding blocks

Introduction

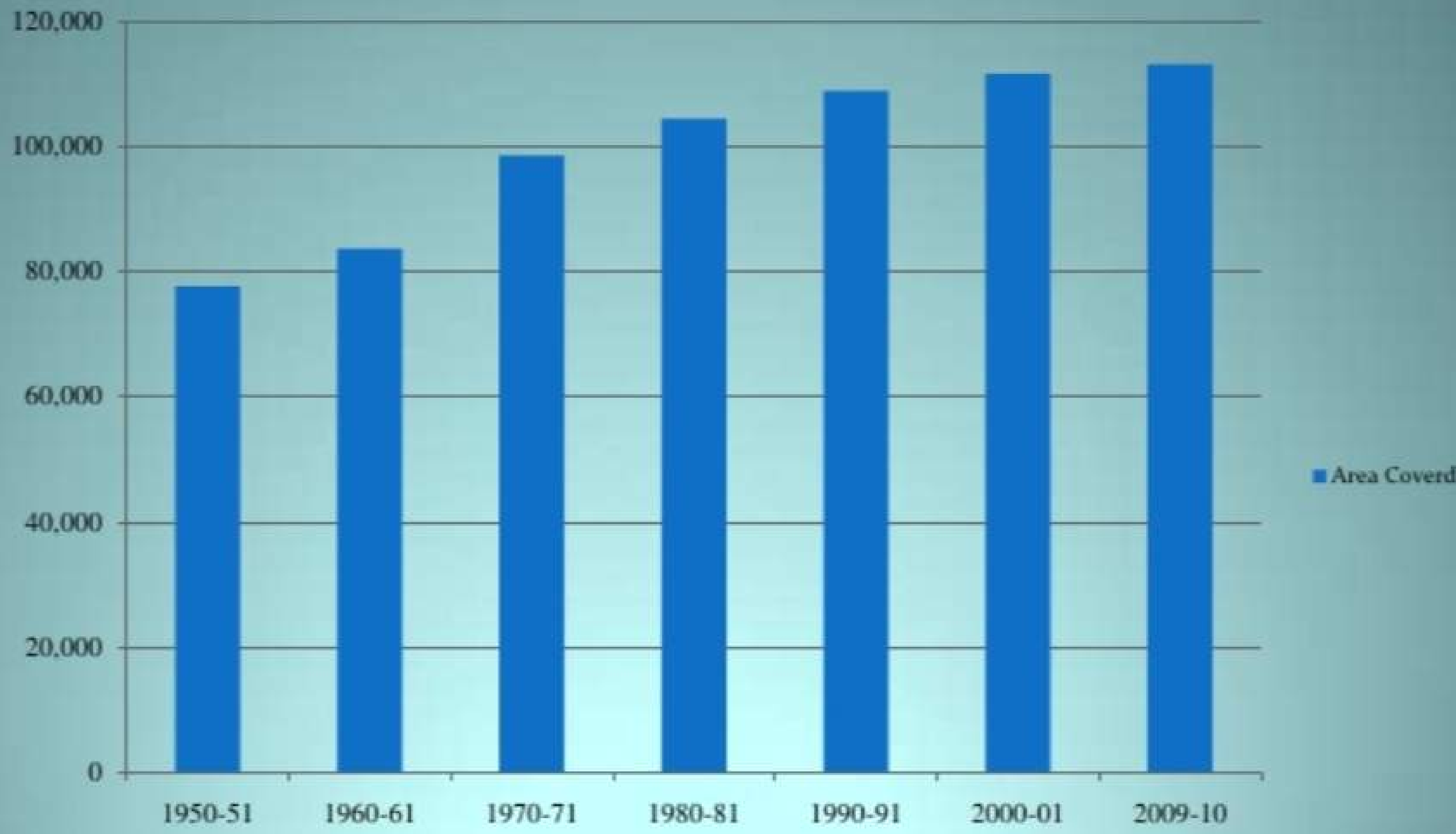
- Indian Railways was introduced in 1853.
- Indian railways work under only 1 management.
- It is a lifeline of country.
- It is biggest civilian employer in the world .
- No strike in last 35 years in spite of 17 lakh workers.
- Always targeted by public during any rally, agitation etc.

Fact & Figures of Indian Railways

- The total area that is covered by Indian Railways is 1,13,115 kms (76,096 miles as on 31.03.2010)

Year	Total track in kms	
	Electrified	Total
1950-51	1,253	77,609
1960-61	2,259	83,706
1970-71	9,586	98,546
1980-81	13,448	104,480
1990-91	25,305	108,858
2000-01	36,950	111,599
[illegible]	[illegible]	[illegible]

Total Area Coverd by Indian Railways in different years



Other Important Statistics

S.No.	Item	Unit	2015-16	2016-17
I	**Rail Network**			
1	Route Kilometres			
	(i) BG	Kms.	60,510	61,680
	(ii) MG	"	3,880	3,479
	(iii) NG	"	2,297	2,209
	(iv) Total (all gauges)	"	66,687	67,368
2	Running Track Kilometres (Total all gauges)	"	92,084	93,902
3	Total Track Kilometres (Total all gauges)	"	1,19,630	1,21,407
4	Electricfied Route Kilometre (Total all gauges)	"	23,555	25,367
II	**Rolling stock**			
1	Number of Locomotives	(in units)		
	(i) Steam	"	39	39
	(ii) Diesel	"	5,869	6,023
	(iii) Electric	"	5,214	5,399
	(iv) Total	"	11,122	11,461
2	Number of Wagons	"	2,51,295*	2,77,987
3	Number of Coaches-	(in units)		
	(i) Passenger Carriages (including DEMU/ DHMU)	"	54,609*	55,068
	(ii) Other Coaching Vehicles	"	6,704*	6,714
	(iii) EMU and MEMU Coaches	"	8,805	9,125
	(iv) Rail Cars	"	31	30
	(v) Total	"	70,149*	70,937
III	**Loco Utilisation**			
1	Tractive effort per loco			
	(i) BG	Kgs.	37,483	37,808
	(ii) MG	"	17,853	17,746
2	GTKMs (excl. wt. of engine & dept.) per kg. of tractive effort.			
	(i) BG	Kms.	4,314	4,077
	(ii) MG	"	1,240*	461
3	Engine kilometres per day per engine in use (Pass.) (B.G)			
	(i) Diesel	Kms.	607	598

S.No.	Item	Unit	2015-16	2016-17
	(ii) Electric	"	662	709
4	Engine kilometres per day per engine in use (Goods)(B.G)			
	(i) Diesel	Kms.	367	377
	(ii) Electric	"	380	390
5	NTKMs per engine hour (BG) All traction		17,507*	16,337
6	Ineffective percentage of locomotives (B.G)	Percent		
	(i) Diesel	"	8.76*	8.93
	(ii) Electric	"	6.97*	7.43
IV	**Wagon Utilisation**			
1	Wagon KMs in terms of 8 wheelers	Million	18,708	18,403
2	Total Carrying Capacity (All Gauges)	Million Tonnes	14.39	15.99
3	Average carrying capacity - wagon	Tonnes		
	BG	"	60.8	60.9
	MG	"	33.7*	33.2
4	Wagon Turn Round (in days) (BG)	Days	5.18	5.32
5	Wagon Kms. per wagon per day (BG)	Kms	214.5	204.2
6	NTKMs per wagon per day (BG)	Kms	7,510	7,359
7	Ineffective percentage of wagons (B.G)	%age	4.26	3.63
V	**Coach Utilisation**			

V	**Coach Utilisation**			
1	Vehicle Kms	Millions		
	(i) Suburban (EMU)	"	1,970	**2,002**
	(ii) Non Suburban	"	23,358	**24,274**
	(iii) Total	"	25,328	**26,276**
2	Vehicle Kms per vehicle day (B.G)	Kms.	569	**564**
3	Ineffective percentage of coaches(B.G) (Passenger Carriage)	Percent	6.1*	**5.95**
VI	**Train Utilisation**			
a.	**Passenger Train Performance**			
1	Number of Passenger trains runs daily	Nos.	13,313	**13,329**
4	Passenger Train Kms	Millions	771.25*	**788.44**
b.	**Goods Train Performance**			
1	Number of Goods trains runs daily	Nos.	9,212	**9,221**
2	Goods Train Kms.	Millions	397.02*	**391.09**
3	Average Speed of All Goods Train (B.G.)			
	(i) Diesel	Kms./Hour	23	**23.3**
	(ii) Electric	"	23.7	**24.0**

S.No.	Item	Unit	2015-16	2016-17
	(iii) All Traction	"	23.4	**23.7**
4	Average Net load of Goods train (B.G)(All traction)	Tonnes	1,664	**1,600**
5	Average Gross load of Goods train (B.G)(All traction)	Tonnes	2,955*	**2859**
VII	**Volume of traffic**			
a.	**Passenger Traffic (Suburban + Non-Suburban)**			
1	Passenger Originating	Millions	8,107	**8,116**
2	Passenger Kilometres	Millions	11,43,039	**11,49,835**
3	Average Lead	Kms.	141.0	**141.7**
4	Passenger Earnings	₹ in crore	44,283	**46,280**
5	Average rate per PKMs	Paise	38.74	**40.25**
6	Number of Passenger carried per day	Millions	22.21	**22.24**
b.	**Freight Traffic (Revenue)**			
1	Tonnes originating	Millions	1,101.51	**1,106.15**
2	Lead (originating)	Kms.	594	**561**
3	Freight Earnings excl. Demurrarge/Wharfage	₹ in crore	1,06,940.55	**1,02,027.82**
4	Frieght NTKMs	Millions	6,54,481	**6,20,175**
5	Average rate per NTKMs	Paise	163.4	**164.51**
6	Earnings per million tonne	₹ in crore	97.09	**92.21**
7	Freight carried per day (including non-revenue)	Millions Tonnes	3.03	**3.04**
VIII	**Train Accidents (Excl. KRCL)**	Nos.	106	**103**
1	Collisions	"	3	**5**
2	Derailment	"	64	**77**
3	Level Crossing	"	35	**20**
4	Fire in trains	"	-	**1**
5	Miscellaneus	"	4	**0**
6	Accident per million train kms		0.10	**0.09**
IX	**Density**			
1	Net Tonne Kms per route Km. (BG)	Km.	10.83	**10.06**
2	Passenger Kms per route Km. (BG)	"	18.66	**18.49**
3	Gross Tonne Kms per route Km. (BG)	"	32.35	**31.38**
X	**Comsumption of Fuel/Energy by Locomotive**			
	(i) Diesel	Million litres	2,874.95	**2793.20**
	(ii) Electric	Million KWH	15,701.25	**15,666.46**

* revised

GAUGE

The clear horizontal distance between the inner (running) faces of the two rails forming a track is known as Gauge. (see in fig given below) This gauge of 1435 mm has been universally used in Great Britain, France, Germany, U.S.A., Canada and most other countries of Europe and is thus known as the world standard gauge. In India broad gauge used which has standard size 1676 mm.

TYPES OF GAUGES PREVALENT IN INDIA

The different gauges prevalent in ***India*** are of the following these types :-

1. ***Broad gauge (1676),***
2. ***Metre gauge (1000),***
3. ***Narrow gauge (762 mm & 610 mm).***

1. *Broad Gauge* :- When the clear horizontal distance between the inner faces of two parallel rails forming a track is 1676mm the gauge is called Broad Gauge (B.G)

This gauge is also known as standard gauge of India and is the broadest gauge of the world.

The Other countries using the Broad Gauge are Pakistan, Bangladesh, SriLanka, Brazil, Argentine,etc.50% India's railway tracks have been laid to this gauge.

METRE GAUGE

- When the clear horizontal distance between the inner faces of twoparallel rails forming a track is 1000mm, the gauge is known as Metre Gauge (M.G)
  The other countries using Metre gauge are France, Switzerland, Argentine, etc. 40% of India's railway tracks have been laid to this gauge.

NARROW GAUGE:-

- when the clear horizontal distance between the inner faces of two parallel rails forming a track is either 762mm or 610mm, the gauge is known as narrow gauge (n.g)
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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.

4. 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.

Loading gauge

- A **loading gauge** defines the maximum height and width for railway vehicles and their loads to ensure safe passage through bridges, tunnels and other structures.
- The loading gauge determines the sizes of passenger trains and the size of shipping containers that can be conveyed on a section of railway line and varies across the world and often within a single railway system.

Loading gauge

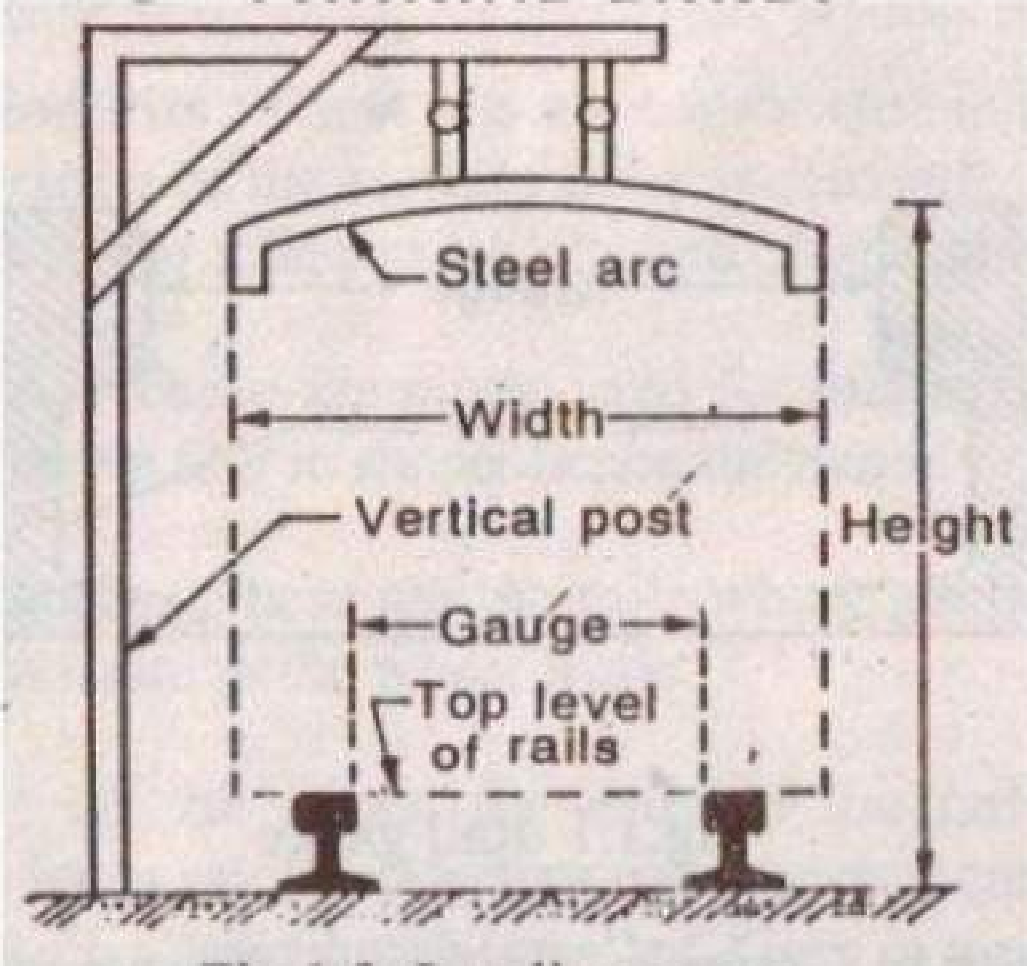

Fig.1.2 Loading gauge

Construction gauge.

- By adding suitable clearance at the top side of the loading gauge construction gauge is obtained.
- It decides the dimensions such as height and width of structures in bridges and tunnels along the track so that all wagons may pass through them without damage to the structures

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Requirements of an ideal rail

The main requirements of an ideal rail section are as under:

(1) The section of the rail should be such that the load of eh wheels is transferred to the sleepers without exceeding the permissible stresses.

(2) The section of the rail should be able to withstand the lateral forces caused due to fast moving trains.

(3) The underside of the head and top of the foot of the rail section should be of such a slope that the fishplates fit easly.

(4) The center of gravity of the rail section should preferably coincide the center of the height of the rail so that maximum tensile and compressive stresses are nearly equal.

(5) The web of the rail section should be such that it can safely
bear the vertical load without buckling.

(6) The head of the rail should be sufficiently thick for adequate margin of vertical wear.

(7) The foot of rail should provide sufficient bearing area on the underlying sleepers so that the compressive stresses on the timber sleeper remain within permissible limits.

(8) The section of the rails should be such that the ends of two adjacent rails can be efficiently jointed with a pair of fish plates.

(9) The surfaces for rail table and gauge face should be sufficiently hard to resist the wear.

(10) The contact area between the rail and wheel flange should be as large as possible to reduce the contact stresses.

(12) The composition of the steel should conform to the specifications adopted for its manufacture by Open Hearth of Duplex Process.

(13) The overall height of the rail should be adequate to provide

sufficient stiffness and strength as a simply supported beam.

(14) The stiffness of a rail section depends upon the moment of inertia.The economical design should provide maximum moment of inertia per unit weigh of rail with due regard to other factors.

(15) The section modulii of the rail section and that of a pair of fish plates should be adequate so as to keep the rail and fish plates within permissible limits.

(16) The foot of the rail should be wide enough so that therail is stable against overturning.

(2) Specification for Rail

The hardness of the rail and wheel materials affects its life through the interaction of the rail and the wheel. The specification of Japanese and Indian rails is as follows.

1) Japanese Rail specification

Table 7-14 Type of Japanese rail

Type	Code	Weight (kg/m)
50kgN Rail	50N	50.4
60kg Rail	60	60.8

Table 7-15 Chemical composition of non-treated rail

Type	C	Si	Mn	P	S
50kgN	0.60 - 0.75	0.10 - 0.30	0.70 - 1.10	Less than 0.035	Less than 0.040
60kg		0.13 - 0.30			

Table 7-16 Mechanical Properties of non-treated rail

Type	Tensile strength kgf/mm^2 $[N/mm^2]$	Elongation %
50N Rail	More than 80 [784]	More than 8
60kg Rail		More than 10

Table 7-17 Chemical composition of Head hardened Rail (JIS E1120)

Type	Chemical composition						
	C %	Si %	Mn %	P %	S %	Cr %	V %
HH340	0.72 - 0.82	0.10 - 0.55	0.70 – 1.10	0.030 max.	0.020 max.	0.20 max.	0.03 max.
HH370		0.10 - 0.65	0.80 – 1.20				

Hardness of rail head shall be HS47 to HS53 in Shore hardness or HB 321 to HB375 in Brinell hardness.

Table 7-18 Mechanical properties of Head hardened Rail

Type	Tensile strength N/mm^2 $[kgf/mm^2]$	Elongation %
HH340	1,080 [110] min.	8 min.
HH370	1,130 [115] min.	

Table 7-19 Surface hardness of vertex part of Head hardened Rail

Type	Shore hardness HSC
HH340	47 – 53
HH370	49 – 56

2) Indian Rail (IRS T-12) specification

Table 7-20 Profile of Indian Rail

Profile	Sectional Wt kg/m
R - 52	51.89
R - 60	60.30

Table 7-21 Specification

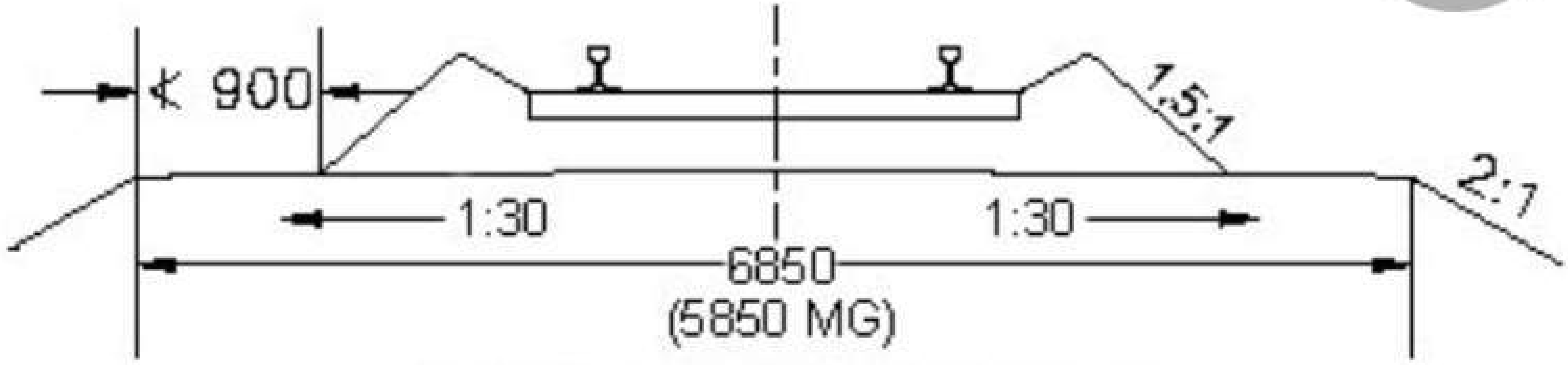
Specification	Grade	Chemical Composition %					Mechanical Properties	
		C	M	P	S	Si	TS MPa	Elong %
IRS-T12/96	880	0.60-0.80	0.80-1.30	0.035 max	0.035 max	0.10-0.50	880 min	10.0

Hydrogen content<3 ppm and Al max 0.02%
Unit Tensile Strength; 90

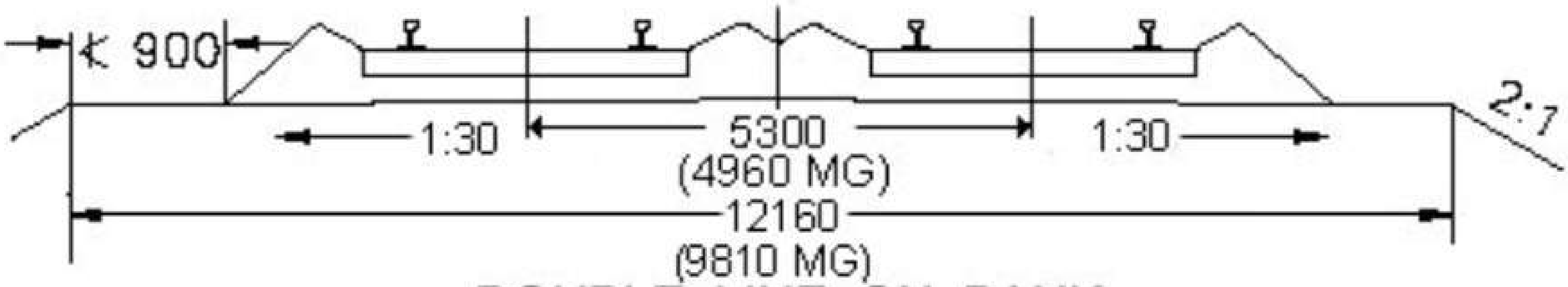
Single-track/ double-track railway

A **single-track** **railway** is a railway where trains traveling in both directions share the same track. Single track is usually found on lesser-used rail lines, often branch lines, where the level of traffic is not high enough to justify the cost of constructing a second track.

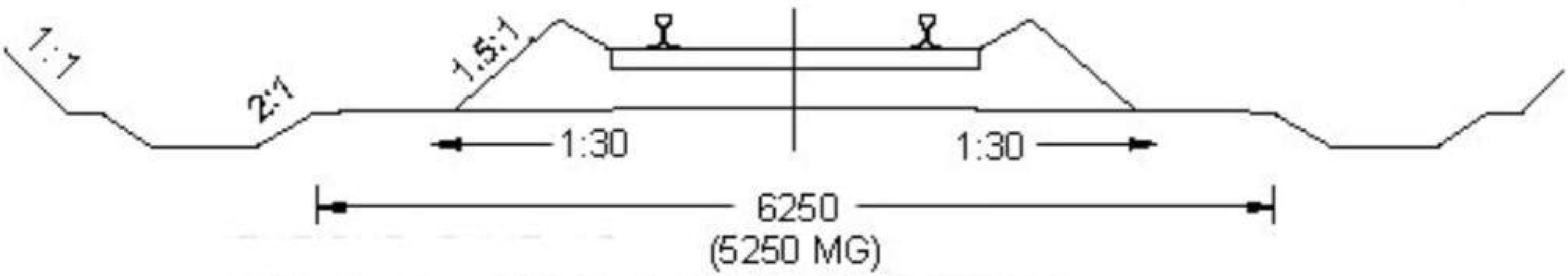
A **double-track** railway usually involves running one track in each direction, compared to a single-track railway where trains in both directions share the same track.



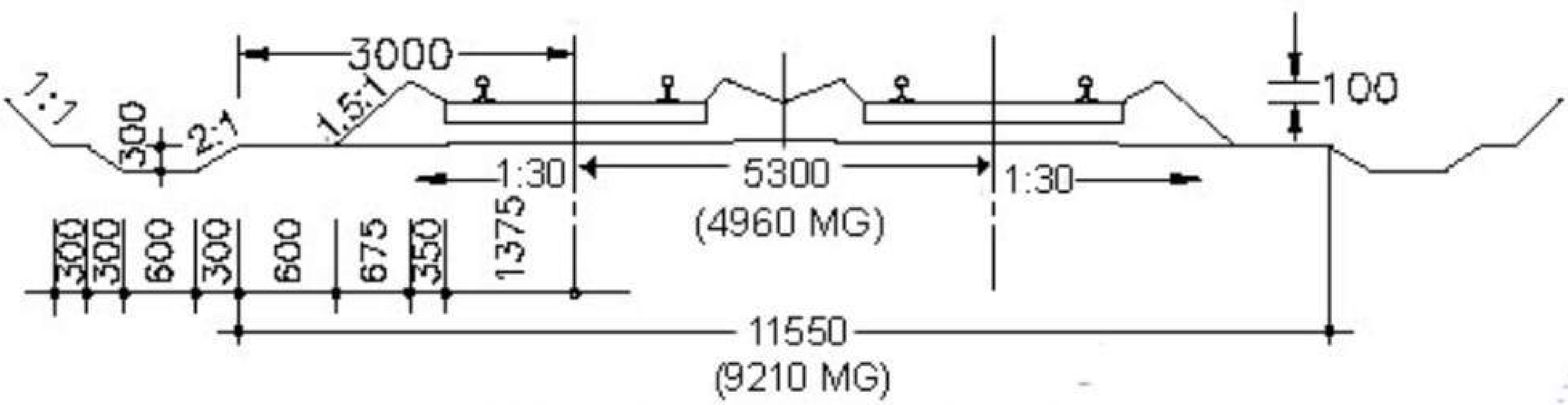
SINGLE LINE ON BANK



DOUBLE LINE ON BANK



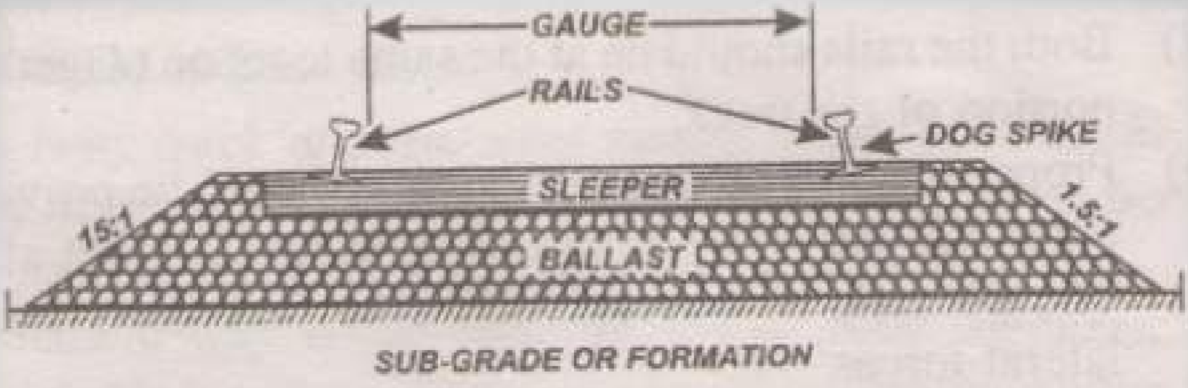
SINGLE LINE IN CUTTING



DOUBLE LINE IN CUTTING

PERMANENT WAY

Permanent way is a track which is permanent in nature which handles the normal commercial traffic.



SECTION OF A RAILWAY TRACK SHOWING GAUGE

The following are the component parts of a permanent way or a railway track :-

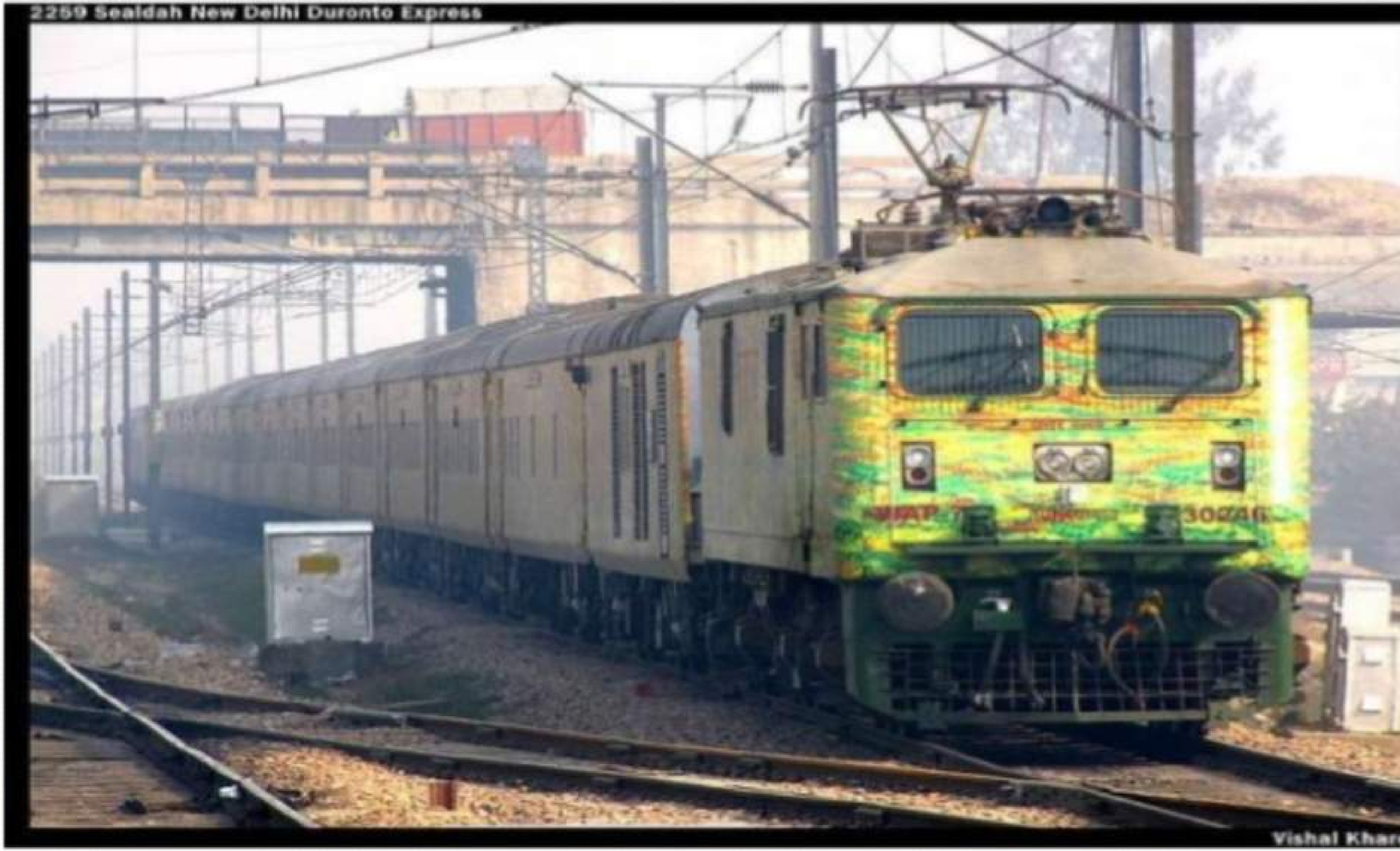
- Formation or sub grade ;
- Ballast ;
- Sleepers ;
- Rails ;
- Fixtures and fastenings.

REQUIREMENTS OF AN IDEAL PERMANENT WAY

The following are the principal requirements of an ideal permanent way or of a good railway track :-

i. The gauge of the permanent way should be uniform, correct and it should not get altered.
ii. Both the rails should be at the same level on tangent (straight) portion of the track.
iii. Proper amount of *super elevation should be provided to the outer rail above the inner rail on curved portion of the track.

RAILWAYS



RAILS

The rolled steel sections laid end to end in two parallel lines over sleepers to form a railway track are known as **RAILS.**

Sleepers

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

Types of Sleepers

- Wooden Sleepers
- Metal Sleepers
- Concrete Sleepers


Wooden Sleepers
4"
(100mm)
8"
(200mm)
8' long
(2.4m)

Concrete Sleepers

Metal Sleeper

BALLAST

- Ballast is the granular material usually broken stone or bricks single and kanker, gravel and sand placed and packed and around the sleeper to transmit Load from sleeper to formation Layer.

Size = 20mm – 65mm

Subgrade and Formation

Subgrade is the naturally occuring soil which is prepared to receive the ballast. The prepared flat surface, which is ready to receive the ballast, sleepers, and rails, is called the formation. The formation is an important constituent of the track, as it supports the entire track structure. It has the following functions.

(a) To provide a smooth and uniform bed for laying the track.

(b) To bear the load transmitted to it from the moving load through the ballast.

(c) To facilitate drainage.

(d) To provide stability to the track. The following points are relevant with respect to the dimensions given in Table 9.1.

(a) The widths have been calculated for a minimum width of 900 mm in banks and 600 mm in cuttings and a ballast profile slope of about 1:1.

(b) The width of a double-line section has been calculated with a track centre of 5.30 m on BG and 3.96 m on MG. These dimensions are based on a ballast cushion of 300 mm.

(c) The side drain should have a minimum of 0.30 m horizontal berm on the side (i.e., on other than the track side) in order to be fully effective.

Table 9.1 Width of formation for different tracks

Table 9.1 Width of formation for different tracks

Gauge	*Type of sleepers*	*Single-line section*		*Double-line section*	
		Bank width (m)	*Cutting width (m)*	*Bank width (m)*	*Cutting width (m)*
BG	W,* ST,† and concrete	6.85	6.25	12.155	11.555
MG	W, ST, CST-9, and concrete	5.85	5.25	9.81	9.21
NG	W, ST, and CST-9	3.70	3.35	7.32	7.01

* W stands for wooden sleepers.
† ST stands for steel trough sleeper.

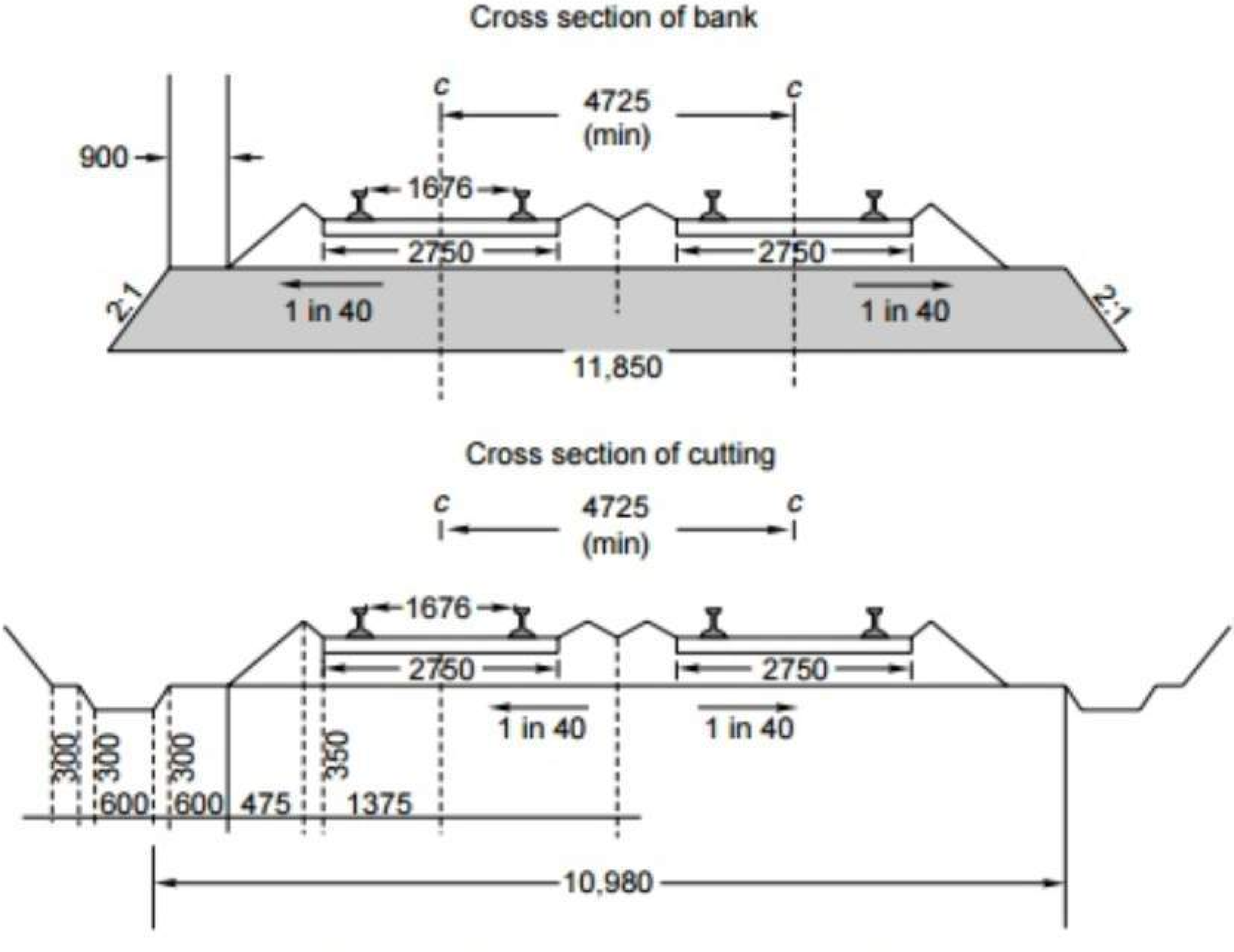


Fig. 9.1 Typical cross section of bank and cutting for BG double line (dimensions in mm)

Track Fittings and Fastenings

Track fittings and rail fastenings are used to keep the rails in the proper position and to set the points and crossings properly.

They link the rails endwise and fix the rails either on chairs fixed to sleepers or directly on to the sleepers.

The important fittings commonly used are:

1. Fish plates
2. Spikes
3. Bolts
4. Chairs
5. Blocks
6. Keys
7. plates

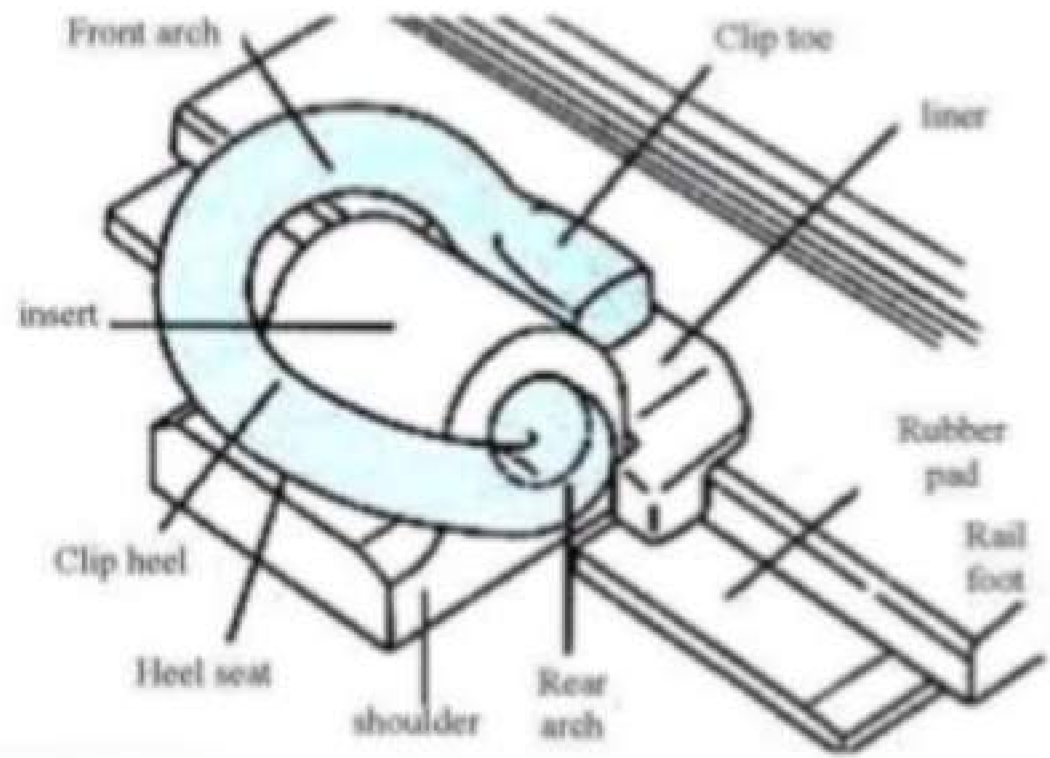


Figure 2: Schematic of rail fastening system used in the Indian Railways

Fish plates: these are used in rail joints to maintain the continuity of the rails and to allow expansion and contraction.

Requirements of fish plates:

- Fish plates should maintain the correct alignment both horizontally and vertically.
- They should support the underside of the rail and top of the foot.
- Provide proper space for the expansion and contraction
- They should be made up of such a section to withstand shocks and heavy stresses due to lateral and vertical B.M

Sections of fish plates:

Various sections have been designed to bear the stresses due to lateral vertical bending.

Standard section is bone shaped

Spikes:

For holding the rails to the wooden sleepers, spikes of various types are used.

Requirements of spikes:

Spikes should be strong enough to hold the rail in position and it should have enough resistance against motion to retain its original position.

The spikes should be deep for better holding power.

It should be easy in fixing and removal from the sleepers.

The spikes should cheap in cost and it should capable of maintaining the gauge.

Blocks: when two rails run very close as in case of check rails, etc. small blocks are inserted in between the two rails and bolted to maintain the required distance.

Bolts: used for fixing various track components in position.

Dog or hook bolt: when sleepers rest directly on girder they are fastened to top flange top flange of the girder by bolts called dog bolts.

Fish bolt: made up of medium or high carbon steel. For a 44.7 kg rail, a bolt of 2.5 cm. dia. and 12.7 cm length is used. With each fish plate standard practice is to use four bolts. Generally, a projection of 6 mm of the shank is left out after the nut is tightened.

Keys:

Keys are small tapered pieces of timber on steel to fix rails to chairs on metal sleepers.

Morgan key:

This is about 18 cm long and tapered 1 in 32. these are suit the C.I chair, plate sleepers and steel sleepers with the rail.

The advantages of morgan keys are

- They can be used as left hand or right hand keys.
- They are light in weight due to double recess on either side.
- They are versatile in nature.

CONING OF WHEELS

By :

Swapnil Mangaonkar

Definition :-

The surface of wheels are made in cone shaped at an inclination of 1 in 20 , and the same slope is provided in the rails.

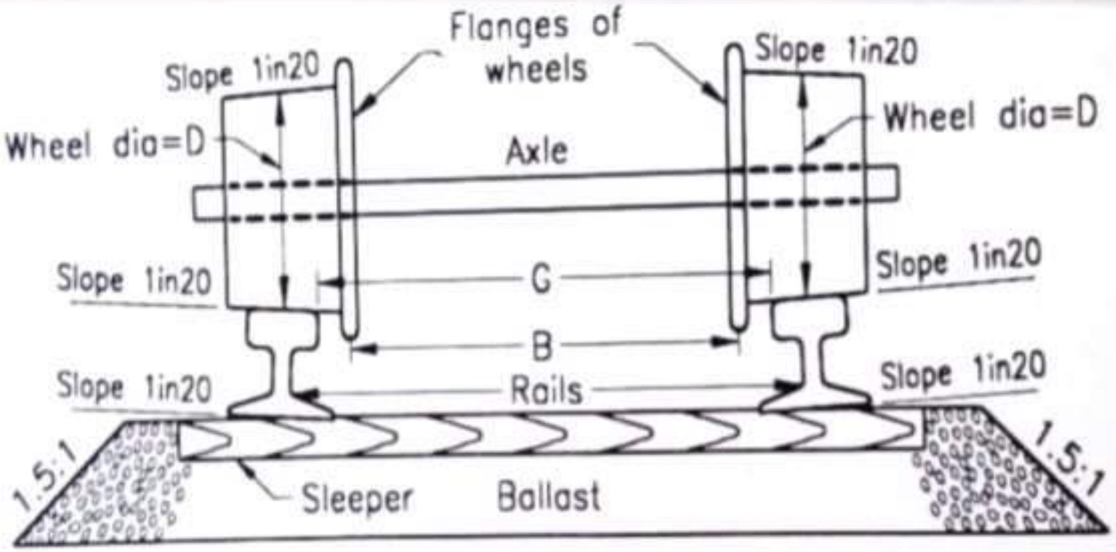
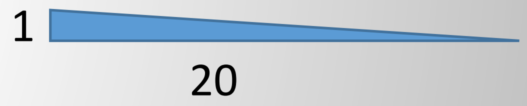


Fig. 3.7 Coning of Wheels on Level-track



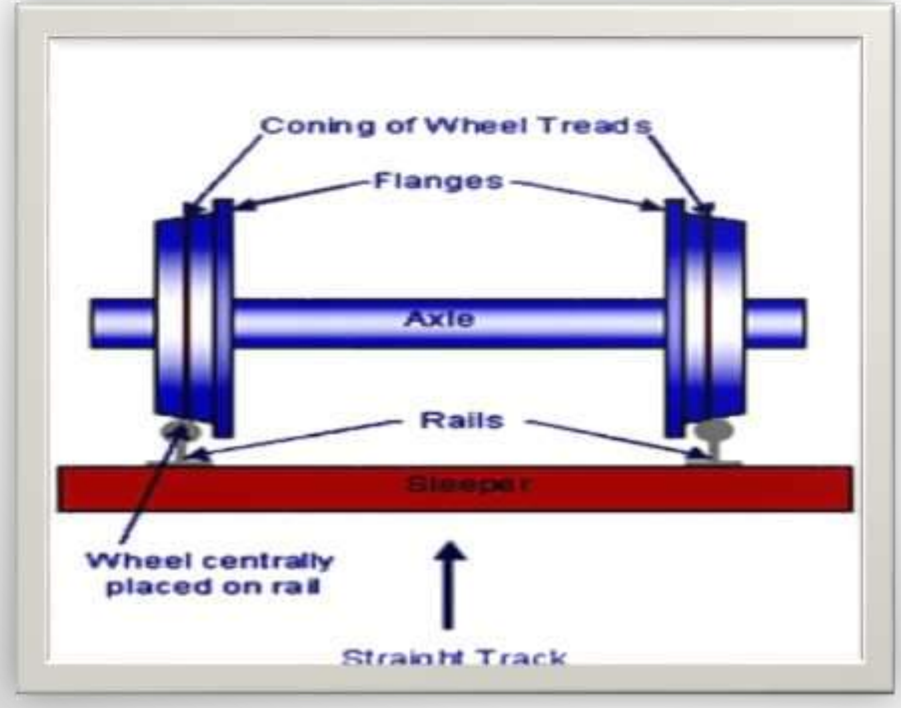
Concept :-

If the tread of the wheels are flat then there will be movement between wheel & rails due to which vehicle not be maintained in central position due to which there will be unequal distribution of load. To avoid that coning of wheels should be done.

How it works :-

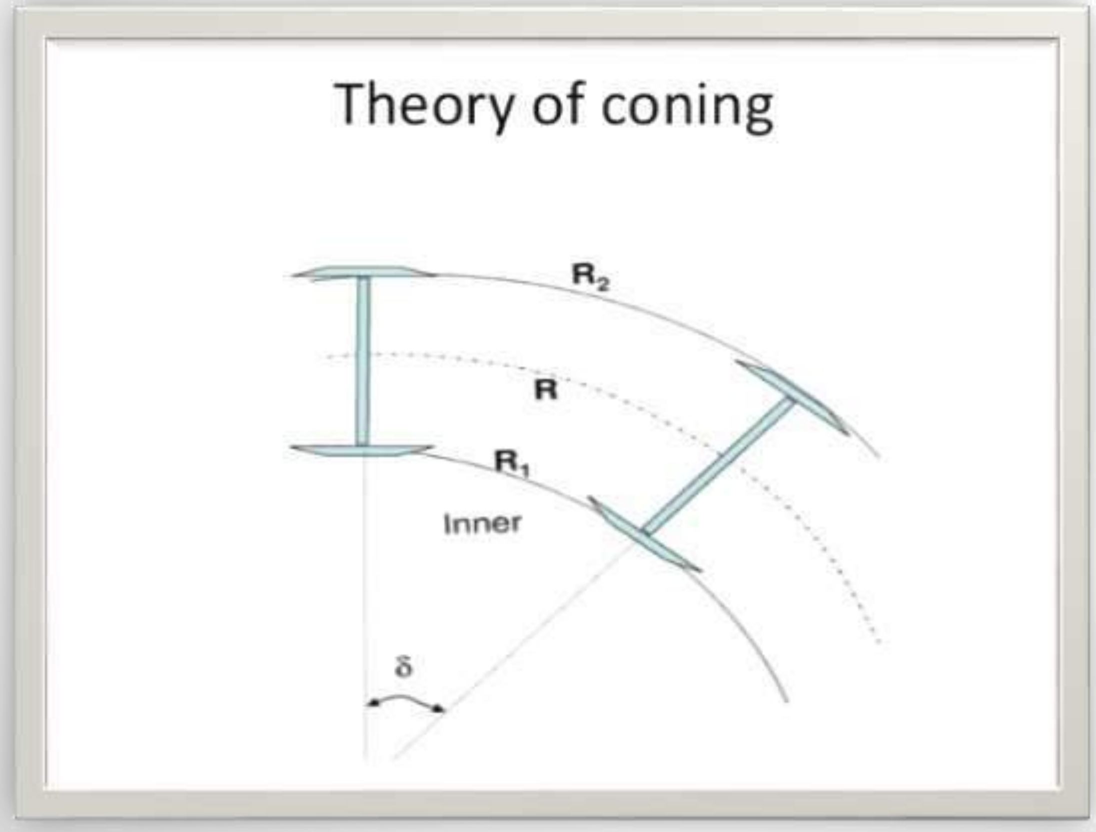
Straight track :-

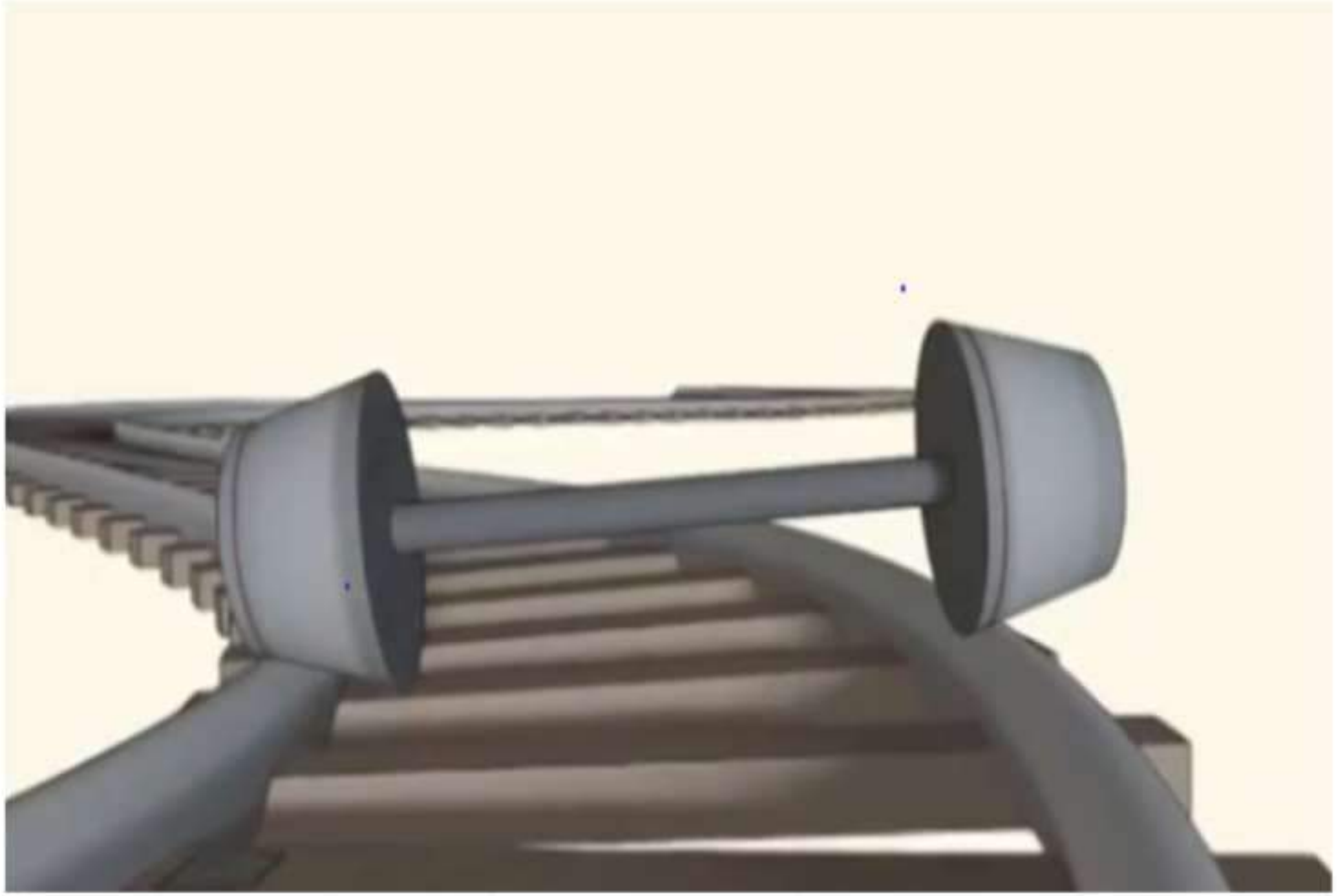
For smooth riding track should not touches the flange for that track should touch centre of the wheel and this insure by coning of wheels.



Curved track :-

For outer wheels have to cover greater distance than inner wheel due to centrifugal force, due to coning of wheels diameter of wheels increases over outer rail and decreases over in inner rail.





Need:-

- To reduce lateral movement of the axle
- To reduce the contact between flange and inner side of the rail.
- Smooth flow of the train on tracks is made possible because of coning of wheels

Disadvantages :-

- Due to centrifugal force , the horizontal components tends to turn out and rail has widening tendency
- If no base plate is used under void sleeper under the age of the rails are damaged.
- Pressure on outer rail is more than inner rail this result in wear of outer rail

- **This disadvantages can be prevent by tilting of the rails.**

Tilting of Rails.

Rails are **tilted** inward at an angle of 1 in 20 to reduce wear and tear on the **rails** as well as on the tread of the wheels. **Rails** are **tilted** inward at an angle of 1 in 20 to reduce wear and tear on the **rails** as well as on the tread of the wheels.

Adzing of Sleepers:

In order to obtain an inward slope of 1 in 20 for the rail, sleepers are adzed to form a table at this slope at the rail seat.

This process is known as adzing of sleepers. Generally adzing is done for wooden sleepers.

For smooth and comfortable journey accurate adzing is required.

Types of Rail Joints

- Types according to position of joints
  - Square joints
  - Staggered joints
- Types according to position of sleepers
  - Suspended joints
  - Supported joints
  - Bridge joints

- Square joints
  - When a joint in one rail is exactly opposite to the joint in the parallel rail it is called as square joint.
  - Very common type of joint in straight track.
  - Also most preferred.
- Staggered joints
  - When a joint in one rail is exactly opposite to the center of the parallel rail length it is called as staggered joint.

Suspended Joints

- The rail joint when placed at the center of 2 consecutive sleepers is known as suspended joint.
  - Load is equally distributed on sleepers
  - When the joint is pressed down both the rail ends are pressed down evenly.
  - More commonly adopted
  - Provide greater elasticity to the track
  - Cause less disturbance to the wave motion of track
  - Require more maintenance

Supported Joints

- Sleeper is placed exactly below the joint
  - It appears like rails are supported at weakest part.
  - These are not used at present
  - Supported joint did not give sufficient support to the heavy axle loads
  - If the joint is packed too hard it prevents it from settling at times
  - It leads to the battering of rails as wave motion is not carried uniformly.

Bridge joints

- It is similar to suspended joint.
- Difference is here, a sufficient length of metal is used to connect the ends of 2 rails, so that there is no bending stress in the rail.
  - Bridge is placed at bottom of rails and rests on sleepers
  - Sleepers at the end will have to be notched out at the sides or will have to be placed at a lower level than other sleepers to accommodate bridge.

What is Rail Creep

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

Causes of Creep

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

- Major Causes o Creep
- Minor Causes of Creep

Airport Engineering

Airport engineers design and construct airports. Airport engineers must account for the impacts and demands of aircraft in their design of airport facilities. These engineers must use the analysis of predominant wind direction to determine runway orientation, determine the size of runway border and safety areas, different wing tip to wing tip clearances for all gates and must designate the clear zones in the entire port. Aviation is the design, development, production, operation, and use of aircraft.

Role of Air transportation:

- Improves accessibility to otherwise inaccessible areas
- Provides continuous connectivity over land and water (no change of equipment)
- Saves productive time, spent on journey
- Increase the demand of specialized technical skill workforce
- Adds to the foreign reserve through tourism
- Speed: Modern jet can travel at 1000 km/h
- Promotion of trade and commerce

- Military use

- Relief and rescue operations

- Aerial photography

AIRPORT SCENARIO IN INDIA

Introduction

Since its beginning in the early twentieth century, civil aviation has become one of the most fascinating, important, and complex industries in the world. The civil aviation system, particularly its airports, has come to be the backbone of world transport and a necessity to twenty-first-century trade and commerce. In 2008, the commercial service segment of civil aviation, consisting of more than 900 airlines and 22,000 aircraft, carried more than 2 billion passengers and 85 million tons of cargo on more than 74 million flights to more than 1700 airports in more than 180 countries worldwide. Millions more private, corporate, and charter "general aviation" operations were conducted at thousands of commercial and general aviation airports throughout the world. In many parts of the world, commercial service and general aviation serve as the primary, if not the only method of transportation between communities.

The magnitude of the impact of the commercial air transportation industry on the world economy is tremendous, contributing more than $2.6 trillion in economic activity, equivalent to 8 percent of the world gross domestic product, and supporting 29 million jobs.

Air transport scenario in India

The first commercial flight in India was made on February 18, 1911 by Henri Piquet, a frenchman. The flight was planned from Allahabad to Naini junction which is a distance of 7 km L5 miles). Same year Sir George Loyd undertook the rganization of air flying between Bombay and Karachi. Air xvice between these cities were considered as purely mporary and was taken as a government venture.

In 1927 British government established Civil Aviation epartmenl and (his organization helped in building up of a w aerodromes and bringing up of some flying clubs. A gular weekly service commenced between Karachi and elhi in 1929 under Imperial Airways Service. In 1939 Tata \rways Limited started internal air services between Allahabad, Calcutta and Colombo. Later, Indian Trans-Continental Airways mited was formed for the foreign flights in 1933.

The second world War helped this country for having large tmber of technical personnel.

Air Transport Licensing Board came into being in 1946. Tata airlines changed its name as Air India Limited in July 1946 here were about eleven operating units by 1947. The night rvic.es commenced in 1949. For external air services, the Jvernment of India entered in agreement in November 1947, th a new formed organization, named as Ait India International mited. It inaugurated its first international service to London June 8, 1948 via Cairo and Geneva with a fleet of three

constellation-749 aircraft. The initial frequency of one flight a week was gradually stepped up to seven Super-Constellation services a week with alternate stops at Paris, Prague, Duesseidorf, Zurich, Geneva, - Rome, Cairo, Beirut and Damascus.

Master Committee 1952 recommended the formation of Civil Aviation Board as a statutary body. Air Transport Corporation Bill was passed on May 14, 1953. Under this bill two corporations were established, one for operating international services and the other for domestic services. The domestic operations were taken over by the Indian Airlines Corporation. Similarly, Air India. International Limited was renamed as Air India International Corporation. On August 1, 1953 airlines were nationalised.

In April 1960, Air India celebrated entry into the jet age by starting Boeing 707 services to London and later in May to New York—thus becoming the first Asian carrier to operate over the Atlantic.

In July 1967, the Government, of India set up the International Airports Committee under the chairmanship of Mr. J. R. D Tata to advise the Government regarding the improvement which are required in the existing international airports it India in view of the continuous growth of air traffic and the likely introduction of very large subsonic and supersonic aircrafts in near future. The interim report of the committee was submitted to the Government in April, 1968. On January 2, 1971, Indian Airlines inaugurated the daily Boeing 737 service on the Bombay-Calcutta and Delhi-Bombay sectors. The country for domestic flights is divided in to four flight information regions with centres at Delhi, Bombay Madras and Calcutta.

International Airport Authority of India (IAAI) was set u in April 1972 for the operation, management, planning an development of the four international airports.

The first commercial flight in India was made on February 18, 1911, when a French pilot Monseigneur Piguet flew airmails from Allahabad to Naini, covering a distance of about 10 km in as many minutes. Tata Services became Tata Airlines and then Air-India and spread its wings as Air-India International. The domestic aviation scene, however, was chaotic. When the American Tenth Air Force in India disposed of its planes at throwaway prices, 11 domestic airlines sprang up, scrambling for traffic that could sustain only two or three. In 1953, the government nationalized the airlines, merged them, and created Indian Airlines. For the next 25 years JRD Tata remained the chairman of Air-India and a director on the board of Indian Airlines. After JRD left, voracious unions mushroomed, spawned on the pork barrel jobs created by politicians. In 1999, A-I had 700 employees per plane; today it has 474 whereas other airlines have 350.

For many years in India air travel was perceived to be an elitist activity. This view arose from the "Maharajah" syndrome where, due to the prohibitive cost of air travel, the only people who could afford it were the rich and powerful.

In recent years, however, this image of Civil Aviation has undergone a change and aviation is now viewed in a different light - as an essential link not only for international travel and trade but also for providing connectivity to different parts of the country. Aviation is, by its very nature, a critical part of the infrastructure of the country and has important ramifications for the development of tourism and trade, the opening up of inaccessible areas of the country and for providing stimulus to business activity and economic growth.

Until less than a decade ago, all aspects of aviation were firmly controlled by the Government. In the early fifties, all airlines operating in the country were merged into either Indian Airlines or AirIndia and, by virtue of the Air Corporations Act, 1953; this monopoly was perpetuated for the next forty years. The Directorate General of Civil Aviation controlled every aspect of flying including granting flying licenses, pilots, certifying aircrafts for flight and issuing all rules and procedures governing Indian airports and airspace. Finally, the Airports Authority of India was entrusted with the responsibility of managing all national and international air ports and administering every aspect of air transport operation through the Air Traffic Control. With the opening up of the Indian economy in the early Nineties, aviation saw some important changes. Most importantly, the Air Corporation Act was repealed to end the monopoly of the public sector and private airlines were reintroduced.

STAGES OF DEVELOPMENT

Introduction

An airport system plan is a representation of the aviation facilities required to meet the immediate and future needs of a metropolitan area, region, state, or country. The system plan presents the recommendations for the general location and characteristics of new airports and heliports and the nature of expansion for existing ones to meet forecasts of aggregate demand. It identifies the aviation role of existing and recommended new airports and facilities. It includes the timing and estimated costs of development and relates airport system planning to the policy and objectives of the relevant jurisdiction. Its overall purpose is to determine the extent, type, nature, location, and timing of airport development needed to establish a viable, balanced, and integrated system of airports. It also provides the basis for detailed airport planning such as that contained in the airport master plan.

The airport system plan provides both broad and specific policies, plans, and programs required to establish a viable and integrated system of airports to meet the needs of the region. The objectives of the system plan include:

1. The orderly and timely development of a system of airports adequate to meet present and future aviation needs and to promote the desired pattern of regional growth relative to industrial, employment, social, environmental, and recreational goals.
2. The development of aviation to meet its role in a balanced and multimodal transportation system to foster the overall goals of the area as reflected in the transportation system plan and comprehensive development plan.
3. The protection and enhancement of the environment through the location and expansion of aviation facilities in a manner which avoids ecological and environmental impairment.
4. The provision of the framework within which specific airport programs may be developed consistent with the short- and long-range airport system requirements.
5. The implementation of land-use and airspace plans which optimize these resources in an often constrained environment.
6. The development of long-range fiscal plans and the establishment of priorities for airport financing within the governmental budgeting process.

7. The establishment of the mechanism for the implementation of the system plan through the normal political framework, including the necessary coordination between governmental agencies, the involvement of both public and private aviation and nonaviation interests, and compatibility with the content, standards, and criteria of existing legislation. The airport system planning process must be consistent with state, regional, or national goals for transportation, land use, and the environment.

The elements in a typical airport system planning process include the following:

1. Exploration of issues that impact aviation in the study area
2. Inventory of the current system
3. Identification of air transportation needs
4. Forecast of system demand
5. Consideration of alternative airport systems
6. Definition of airport roles and policy strategies
7. Recommendation of system changes, funding strategies, and airport development
8. Preparation of an implementation plan

Although the process involves many varied elements, the final product will result in the identification, preservation, and enhancement of the aviation system to meet current and future demand. The ultimate result of the process will be the establishment of a viable, balanced, and integrated system of airports.

National and international organisations of air transport

The **International Air Transport Association** (**IATA**) is a trade association of the world's airlines founded in 1945. IATA has been described as a cartel since, in addition to setting technical standards for airline, IATA also organized tariff conferences that served as a forum for price fixing.Consisting of 290 airlines, primarily major carriers, representing 117 countries, the IATA's member airlines account for carrying approximately 82% of total available seat miles air traffic.
ITATA supports airline activity and helps formulate industry policy and standards. It is headquartered in Canada in the city of Montréal, with Executive Offices in Geneva, Switzerland.

National Air Transport was a large United States airline; in 1930 it was bought by Boeing. The Air Mail Act of 1934 prohibited airlines and manufacturers from being under the same corporate umbrella, so Boeing split into three smaller companies, one of which is United Airlines, which included what had been National Air Transport.

Introduction

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

The elements of a large airport are shown in Fig. 4-1. It is divided into two major components, the airside and the landside. The aircraft gates at the terminal buildings form the division between the two components. Within the system, the characteristics of the vehicles, both ground and air, have a large influence on planning. The passenger and shipper of goods are interested primarily in the overall door-to-door travel time and not just the duration of the air journey. For this reason access to airports is an essential consideration in planning.

The problems resulting from the incorporation of airport operations into the web of metropolitan life are complex. In the early days of air transport, airports were located at a distance from the city, where inexpensive land and a limited number of obstructions permitted flexibility in airport operations. Because of the nature of aircraft and the infrequency of flights, noise was not a problem to the

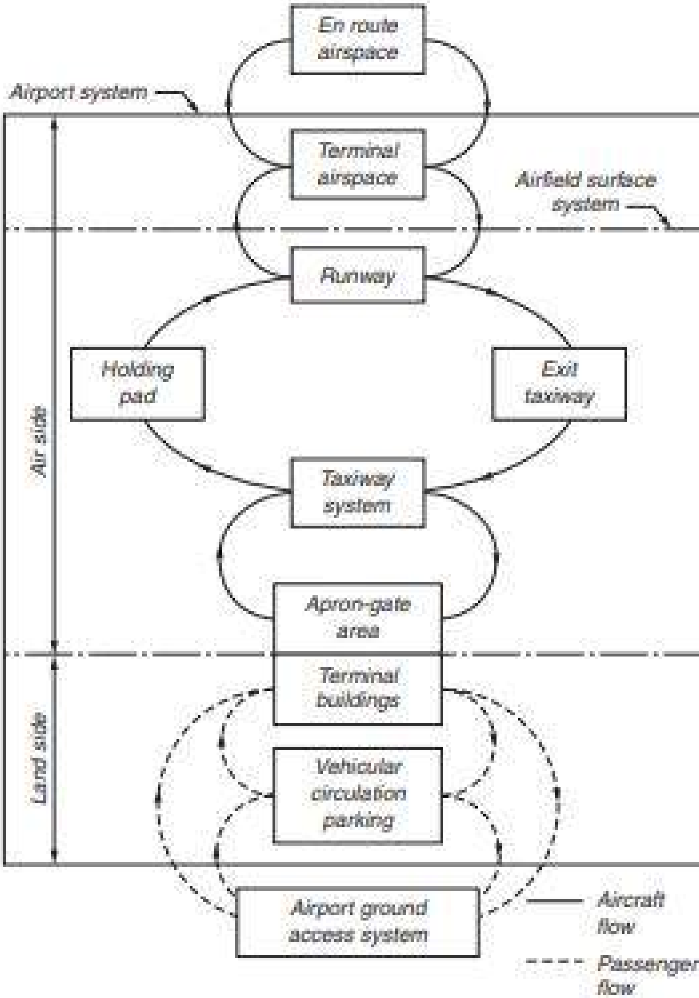


Figure 4-1 Components of the airport system for a large airport.

community. In many cases the arrival and departure of passenger and cargo planes was often a source of local pride. In addition, low population density in the vicinity of the airport and light air traffic prevented occasional accidents from alarming the community. In spite of early lawsuits, the relationship between airport and community was relatively free of strife resulting from problems of nuisance or hazard.

Airport operations have been increasingly hampered by obstructions resulting from industrial development related to the airport and from industry attracted by adjacent inexpensive land and access to the transportation afforded by the airfield and its associated highways.

While increasingly dense residential development has resulted from this economic stimulation, one must not overlook the effects of the unprecedented suburban spread during the post-World War II era, resulting from the backlog of housing needs and a period of economic prosperity.

Radical developments in the nature of air transport have produced new problems. The phenomenal growth of air traffic has increased the probability of unfavorable community reaction, but developments in the aircraft themselves have had the most profound effect on airport community relations. The greater size and speed of aircraft have resulted in increases in approach and runway requirements, while increases in the output of power plants have brought increases in noise. Faced with these problems the airport must cope with the problems of securing sufficient airspace for access to the airport, sufficient land for ground operations, and, at the same time, adequate access to the metropolitan area.

SITE SELECTION

Introduction

The emphasis in airport planning is normally on the expansion and improvement of existing airports. However if an existing airport cannot be expanded to meet the future demand or the need for a new airport is identified in an airport system plan, a process to select a new airport site may be required.

- ✓ Identification
- ✓ Screening
- ✓ Operational capability
- ✓ Capacity potential
- ✓ Ground access
- ✓ Development costs
- ✓ Environmental consequences
- ✓ Compatibility with area-wide planning
- ✓ Selection

THE AIRPORT MASTER PLAN

An airport master plan is a concept of the ultimate development of a specific airport. The term development includes the entire airport area, both for aviation and nonaviation uses, and the use of land adjacent to the airport. It presents the development concept graphically and contains the data and rationale upon which the plan is based. Master plans are prepared to support expansion and modernization of existing airports and guide the development of new airports.

The overall objective of the airport master plan is to provide guidelines for future development which will satisfy aviation demand in a financially feasible manner and be compatible with the environment, community development, and other modes of transportation.

More specifically it is a guide for

1. Developing the physical facilities of an airport
2. Developing land on and adjacent to the airport
3. Determining the environmental effects of airport construction and operations

4. Establishing access requirements

5. Establishing the technical, economic and financial feasibility of proposed developments through a thorough investigation of alternative concepts

6. Establishing a schedule of priorities and phasing for the improvements proposed in the plan

7. Establishing an achievable financial plan to support the implementation schedule

8. Establishing a continuing planning process which will monitor conditions and adjust plan recommendations as circumstances warrant

Guidelines for completing an airport master plan are described by ICAO and in the United States by. A master plan report is typically organized as follows:

- ✓ Master plan vision, goals, and objectives
- ✓ Inventory of existing conditions
- ✓ Forecast of aviation demand
- ✓ Demand/capacity analysis and facility requirements
- ✓ Alternatives development
- ✓ Preferred development plan
- ✓ Implementation plan
- ✓ Environmental overview
- ✓ Airport plans package
- ✓ Stakeholder and public involvement

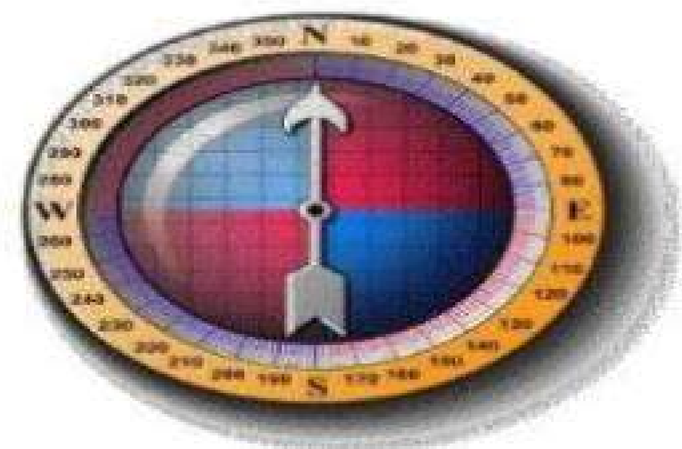
RUNWAY ORIENTATION

According to the International Civil Aviation Organization (ICAO) a runway is a "defined rectangular area on a land aerodrome prepared for the landing and takeoff of aircraft".

The orientation of the runway is an important consideration in airport planning and design. The correct runway orientation maximizes the possible use of the runway throughout the year accounting for a wide variety of wind conditions. FAA and ICAO regulations establish rules about runway orientation and their expected coverage Runway Location Considerations. FAA mandates identification standards for airport layout that is meant to assist pilots in easily recognizing runways.

Ideally, all aircraft operations on a runway should be conducted **against** the wind. Unfortunately, wind conditions vary from hour to hour thus requiring a careful examination of prevailing wind conditions at the airport site. The challenge for the designer is to accommodate all of the aircraft using the facility in a reliable and reasonable manner.

In navigation, all measurement of direction is performed by using the numbers of a compass. A compass is a 360° circle where 0/360° is North, 90° is East, 180° is South, and 270° is West, as shown in figure.



How Runway Orientation Is Decided?

- For normal fixed-wing aircraft it is advantageous to perform take-offs and landings into the wind. This is to increase the speed of air over the wings i.e. flying speed, at a relatively lower ground speed which reduces the actual take-off or landing distance needed. Thus, runway orientations are decided on the historical winds and directions. If the winds are more variable in direction and the airport is large enough to financially justify the investment, airports can have several runways in different directions, so that a runway can be selected that is most nearly aligned with the wind.

Headwind

By taking off into the wind (the wind will generate part of the required lift) the aircraft lifts off sooner and this will result in a lower ground speed and therefore a shorter takeoff run for the aircraft to become airborne. It is therefore recommended.

Not only for safety reasons: a takeoff that is abandoned will also use less runway to stop because ground speed is lower (check the ASDA distance during preflight). Climbing into the wind will result in a steeper climb, which is ideal for clearing obstacles in your climb out path.

Landing into the wind has the same advantages, it uses less runway, ground speed is lower at touchdown (less wear and tear on the aircraft) and the runway is available sooner for the next aircraft when it gets a bit crowded.

A rule of thumb says that takeoff and landing distances are reduced 1,5 % for each knot of headwind up to 20 knots.

Crosswinds are winds that come at an angle to your aircraft in flight and on approach/takeoff, and they can impact your flight operations, fuel burn, and passenger comfort. It's always important to consider the crosswind potential in your pre-trip planning – especially for required fuel loads, tech stops and alternate planning.

The following is an overview of what you need to know:

1. Crosswinds impact operations at altitude

When you are faced with crosswinds along your anticipated route of flight, knowing the crosswind component will help you calculate fuel requirements. It's important to ensure that proper fuel amounts are uplifted based on the wind component of your flight plan. If you're operating near the jet stream, crosswinds can have a major impact. When you cross the North Atlantic or

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2. Avoiding turbulence at altitude

Avoiding in-flight turbulence is a major operator consideration. Many operators want to avoid turbulence at all costs. A shear value of 5 may be the highest some operators will accept. Best practice is to look at weather patterns two to three days out and determine how forecasted weather systems will impact your flight and specifically the jet stream. Particularly with tailored aviation weather briefs, you'll be well positioned to determine best route of flight and tech stop locations. Depending on the part of the world you're operating to, planning for turbulence avoidance may involve revising overflight permits prior to operation. This requires additional advance planning, as international overflight permits may be difficult to obtain on the day of flight.

3. Determining strength and direction of wind

Upper wind readings are taken from 1) Pibal (weather balloons that send back information to the observer) from various stations in the world and 2) pilot reports (PIREPS). This information is programmed into a weather model to determine direction, strength, and movement of future upper winds and jet streams. Over recent years weather models have become very good at predicting movement of jet streams. In the geostrophic (frictionless) layer (300-150 millibars), winds do not change readily from day to day and can be accurately calculated. If the pilot is attempting to calculate the crosswind component for arrival or departure, consulting the latest surface observation for the airport will provide existing conditions. Also, the terminal forecast will provide a good assessment of proposed wind direction and speed so that the pilot can accurately calculate his crosswind factor.

A "wind rose" diagram is the most common way of displaying wind data, and can be measured in a "speed distribution" or a "frequency distribution". Wind roses can be a yearly average, or can be made for specific seasons; some even include air temperature information.

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

Wind rose diagrams can be plotted in two types

1. showing direction and duration of wind.

2. Showing direction duration and intensity of wind.

Type – I: This type of wind rose is illustrated in fig. the radial lines indicate the wind direction and each circle represents the duration of wind. The values are plotted along the north direction in fig similarly other values are also plotted along the respective directions. All plotted points are then joined by straight lines. The best direction of runway is usually along the direction of the longest lone on wind rose diagram. If deviation of wind direction up to 22.5° + $11.25^\circ$from their direction of runway is thus along NS direction of landing and takeoff is permissible the percentage of time in a year during which runway can safely be used for landing and takeoff will be obtained by summing the percentages of time along NNW, N, NNE, SSE, S and SSW directions. This comes to 57.6 percent. The total percentage of the time therefore comes to 57.0 + 13.5 = 70.5. This type of wind rose does not account for the effect of cross wind component.

Type – II: This type of wind rose is illustrated in fig. the wind data as in the previous type is used for this case. Each circle represents the wind intensity to some scale. The values entered in each

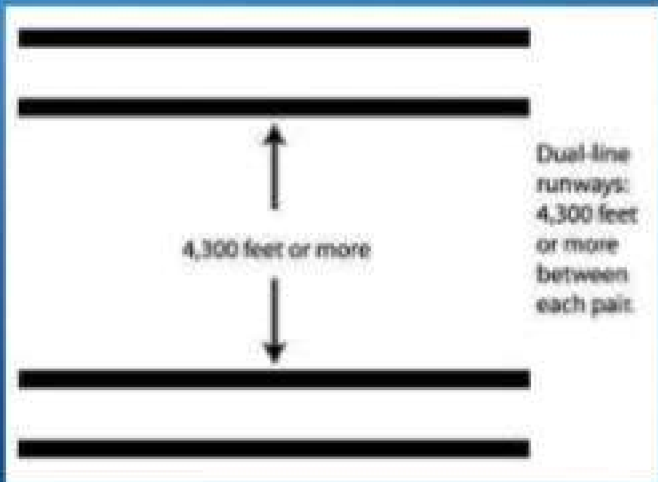
Runway Configuration

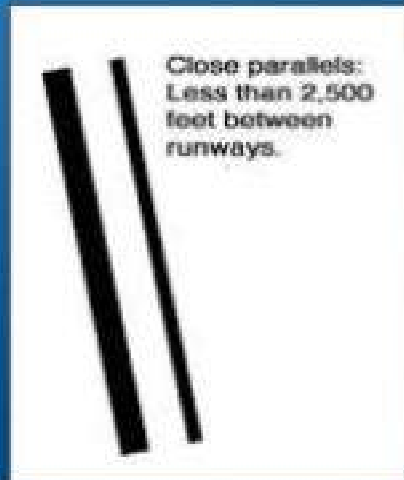
There are four types of Runway Layouts

- **Single runway**
  This is the simplest of the 4 basic configurations. It is one runway optimally positioned for prevailing winds, noise, land use and other determining factors. During VFR (visual flight rules) conditions, this one runway should accommodate up to 99 light aircraft operations per hour. While under IFR (instrument flight rules) conditions, it would accommodate between 42 to 53 operations per hour depending on the mix of traffic and navigational aids available at that airport.

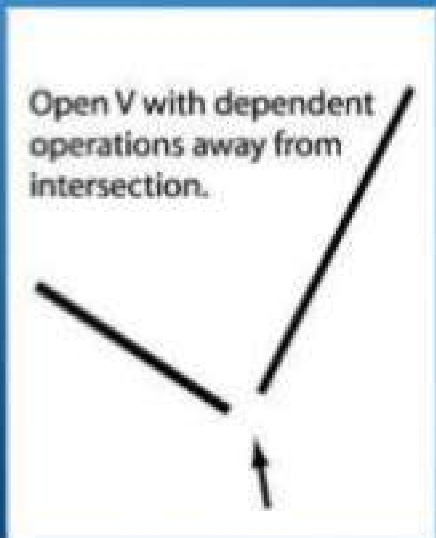
Single runway

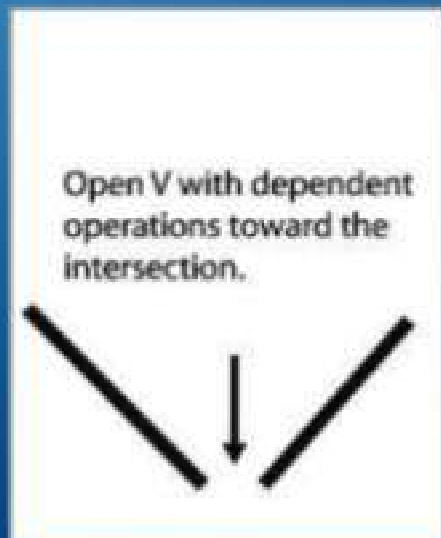
- **Parallel runways**
  There are 4 types of parallel runways. These are named according to how closely they are placed next to each other. Operations per hour will vary depending on the total number of runways and the mix of aircraft. In IFR conditions for predominantly light aircraft, the number of operations would range between 64 to 128 per hour.





- **Open-V runways**
  Two runways that diverge from different directions but do NOT intersect form a shape that looks like an "open-V" are called open-V runways. This configuration is useful when there is little to no wind as it allows for both runways to be used at the same time. When the winds become strong in one direction, then only one runway will be used. When takeoffs and landings are made away from the two closer ends, the number of operations per hour significantly increases. When takeoffs and landings are made toward the two closer ends, the number of operations per hour can be reduced by 50%.





Taxiways

Taxiways are defined as the paths that are used for the taxiing of aircraft from one part of an airport to another. All taxiway markings are yellow.

The different types of taxiway markings are as follows:

- Taxiway Centerline Marking
- Taxiway Edge Marking
- Holding Position Markings
- Markings for a Taxiway in Front of a Runway

Taxiway Centerline Marking

Taxiway centerlines are marked to provide a visual identification of the designated taxiing path. Taxiway centerlines are yellow and consist of a continuous stripe along the centerline of the designated taxiway. On a taxiway curve, the markings continue from the straight portion of the taxiway at a constant distance from the outside edge of the taxiway. A width of between 6 inches and 12 inches wide is acceptable provided the width selected is uniform for its entire length. The centerline will be continuous in length except where it intersects a holding position marking or runway marking element. For taxiway intersections designed for the straight-thorough method of taxiing, the centerline markings continue straight through the intersection.

At taxiway intersections with a runway end, the taxiway centerline marking is terminated at the runway edge, (with the exception of the situation where there is a displaced threshold, in which case the taxiway centerline may be extended onto the runway displaced area). On taxiways used as an entrance or exit to a runway, the taxiway centerline marking curves onto the runway and extends parallel to the runway centerline marking for 200 feet past the point where the two

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Lecture - 35
Exit Taxiway

Dear students, we are back with the lecture series of course material on Transportation Engineering - II. From the previous lecture, we have started with the taxiways, once we have completed about the runways. A taxiway, as we have discussed, is another important aspect or a component of any airport, which provides the connectivity and access between the runway strip and the terminal building or the apron related to the terminal building. So, in that sense it is one of the component which creates its effect on the airport capacity, because the way by which the aircrafts can be turned around and it can be taken away from the runway strip as fast as possible will create its effect on the total capacity which can be handled by any of the airport.

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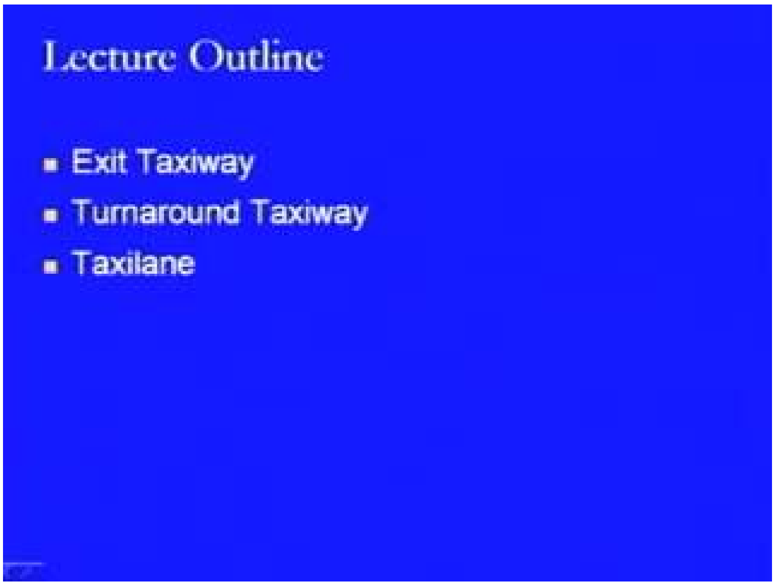

In continuation of the same, so in today's lecture we will be discussing about exit taxiway, a specific type of a taxiway which is used for providing that type of movement from a runway strip to the terminal apron. So, in that case, in this particular lecture we will be taking up exit taxiway, the turnaround taxiway and taxilane. These are the three major components or the three specific types of components of the taxiway which we can discuss.

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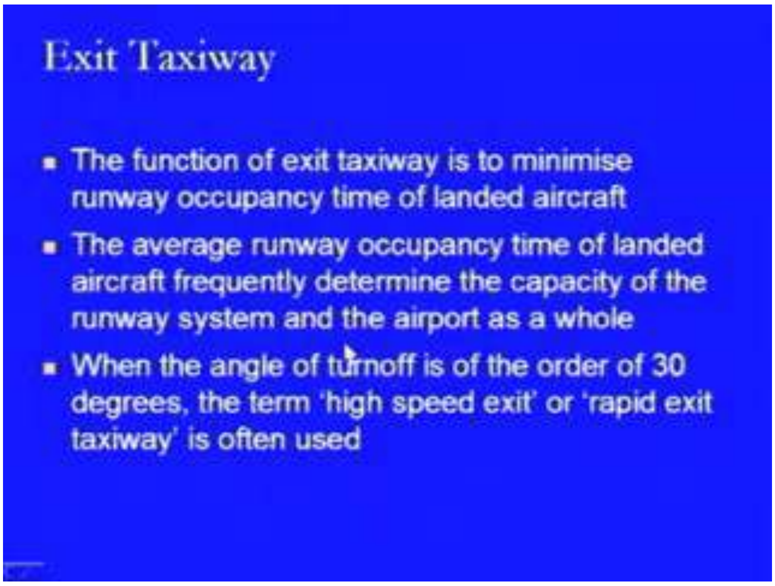

We will be starting with exit taxiway. Exit taxiway, the function of this exit taxiway is basically to minimize the runway occupancy time of landed aircrafts. As we have discussed previously that the taxiway, the main function of a taxiway is to provide an access between runway strip and the terminal building. So, in that sense, it provides the pathway for those aircrafts which have landed on the runway strip and now proceeding towards the terminal building or those aircrafts which are being there on the terminal building apron and now they are proceeding towards the runway strip for take-off.

In both the conditions, as we have seen and we have discussed previously is that, if there are more than one taxiway, then we try to provide the unidirectional movement and in that sense only, here we discussing the exit taxiway, where at number of locations we provide an opportunity from where any landing aircraft can come out of the runway strip, so that the runway is not remain occupied by that aircraft and it can be utilized for another operation, maybe landing or take-off. So, that is why the main function here is or the objective here is to minimize the runway occupancy time.

The average runway occupancy time of any landed aircraft frequently determines the capacity of the runway system and not only the runway system, but it also determines the overall capacity of any airport. So, that is obvious, because if any air aircraft is taking more time at the time of landing before coming towards the terminal building apron, then no other operation can take place on that runway strip. So, it means we are reducing the overall capacity of not only the traffic handling capacity of the runway strip, but also of the airport. So, that is why this average number of occupancy time in an important factor and it is to be measured and optimized in the sense that it is minimum as far as possible.

Now, when the angle of turnoff is of the order of 30 degrees, then the term high speed exit or rapid exit taxilane is used. That depends on at what particular angle the exit taxiway is being provided. If this is being provided at an angle of around 30 degrees, then we say that this turn will be taken up at a higher speed and that is why this is high speed exit or rapid exit taxiway.

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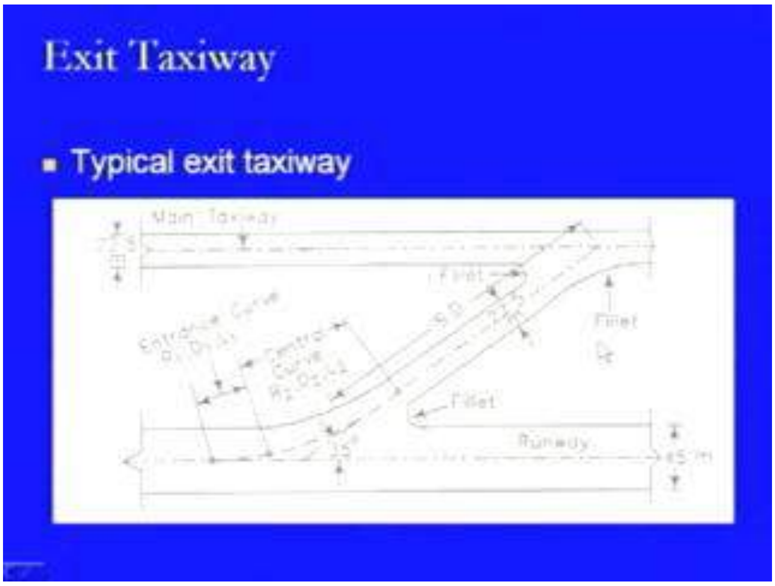

Now, there are certain typical exit taxiways. Now, this is one of the diagrams which try to define that how the taxiway is being, exit taxiway is being provided. Now, here this is the runway strip and on this runway strip an aircraft will be landing from this direction that is from left hand side and will be moving towards the right hand side and there is a taxiway which is parallel lane or parallel pathway or paved area being provided with respect to this runway strip. So, the aircraft has to be taken from this runway strip to this main taxiway, so that this particular runway can be utilized for some other purpose. So, in that sense, a connectivity is being provided between this taxiway and this runway strip and this is what is this type of a connectivity and this connectivity is known as exit taxiway.

That is it is trying to provide an exit from the runway strip and then, it comes towards the taxiway. So, in that sense, the number of design features has been shown here. This is the runway strip which is in natural condition whatever is the width being defined, like here the width being defined here is 45 metres which is for the higher category of an airport and at this level, the angle of turning from this side this is 35 degrees, whereas accordingly from this side it is 180 minus 35 degrees and here, the two curves are being provided. There is one curve which is known as the entrance curve. The length of this entrance is L 1 with the radius R 1 and the degree with which this turn is taking place is defined by D 1, whereas there is a circular central curve which is provided in this location and this is having a length L 2 with the radius R 2 and the deflection angle as D 2.

So, there is a relationship between this deflection angle D 2 and another deflection angle D 1 and that is how we can calculate them as we will be seeing when we will be computing the values for all these different design parameters. Now, in this particular location where there is a turn at this point as we have seen previously or we will be looking in today's lecture too that if there is any plane which is taking a turn, then there are different ways by which it can be done. Either the nose maybe moving along the centreline of the pathway or there is another method in which the pilot uses the judgemental approach and tries to negotiate the curve, wherein the nose gear will be going away from the centreline. But, at the same time, the inner gear of the main gear on the wing will remain within the area, which is away from the inner side of the pavement.

So, in that sense there is always a possibility depending on the type of the method that we are moving away from the edge of the pavement and therefore, this paved area is to be provided which is known as fillet. So, there will be extension of this paved area towards the inner side and that particular area will become the fillet area. Now, here the width of the exit taxiway and the width of the main taxiway is also being shown, which is 22.5 metres, again being provided for a higher category of airports and a fillet is to be provided on this side as well as on this side. So, these two areas are also for fillets and then, there is a side distance which is being provided. This is the side distance being provided from the centre of this curve, central curve towards the point of intersection of this centreline of the exit taxiway with the main taxiway.

At the same time, there is another design parameter which is the distance between the centreline of this main taxiway and the centreline of the runway strip which is termed as the separation distance between the runway and the taxiway. So, that separation distance needs to be calculated. So, these are some design features which have their significance in the design of any exit taxiway and we will be looking at all these design features and the computation of the design parameters.

Now, we first of all look at the conditions, which define the location of any exit taxiway.

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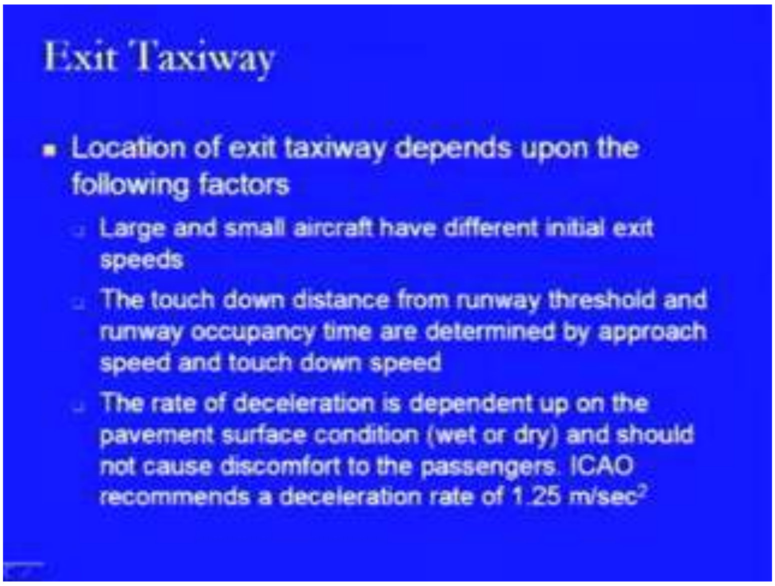

There are certain factors on which this may be depending and the factors are like for large and small aircraft, we may require any different initial exit speeds. That is one particular condition that is also known to us, because it all depends upon the type of the propulsion power which is being provided on any of the aircraft and if the aircraft is big enough, then the power will also be more and therefore, the speed with which it will be landing will be more as compared to the smaller aircrafts. Therefore, we have to look at what is the exit speed of different type of aircrafts which will be using that airport and the exit taxiway.

Then, there is a touch down distance at which the aircraft will be touching the pavement surface, when it is coming along the flight path and descending on the runway strip. So, this touchdown distance from the runway threshold and the runway occupancy time, these both are needed to be determined and they will be dependent on the approach speed with which it is crossing the threshold and the touchdown speed. So, these are the two values which are another important factor or parameter, which will be defining that for how much time period an aircraft is going to remain on the runway strip.

If the aircraft is crossing the runway threshold with the smaller speed, lesser speed, then it will be touching down a little earlier or may touchdown at a pre-specified point, but then it will be coming towards the exit taxiway location with smaller speed and therefore, there is more of occupancy time in this case. Whereas, an aircraft coming with the higher speed, at touchdown location also it is having a higher speed, then it will be moving with the same that big higher speed and therefore, the chances of occupancy time will remain lesser. So, that is another design parameter or factor which will create its effect on occupancy time.

Then, another factor is the rate of de-acceleration here and this rate of this de-acceleration is also dependent on certain parameters like the pavement surface condition. Within this pavement surface condition, it may be a possibility that this is in the wet condition or it is in the dry condition. So, on both these conditions, then it is having a different coefficient of friction which creates its effect. At a time the aircraft is trying to de-accelerate or the pavement surface will be providing some resistance in the opposite direction. Obviously, in the dry condition, the coefficient of friction will be more as compared to wet condition.

So, in that case, in the case of a dry condition, the rate of de-acceleration will be more and therefore, the aircraft can be brought to a desired smaller speed earlier as compared to wet condition and another factor is that this rate of de-acceleration should be such that the passengers should not feel jerks or there should not be any discomfort to them at the time when the aircraft is trying to reduce its speed. So, these are the two factors which creates its effect or which governs the value of rate of de-acceleration. As far as ICAO is concerned, then ICAO has recommended de-acceleration rate of 1.25 metre per square second. So, that is the rate which can be used if it is not being specified, otherwise by any of the other airport authority governing the air navigation in any of the country.

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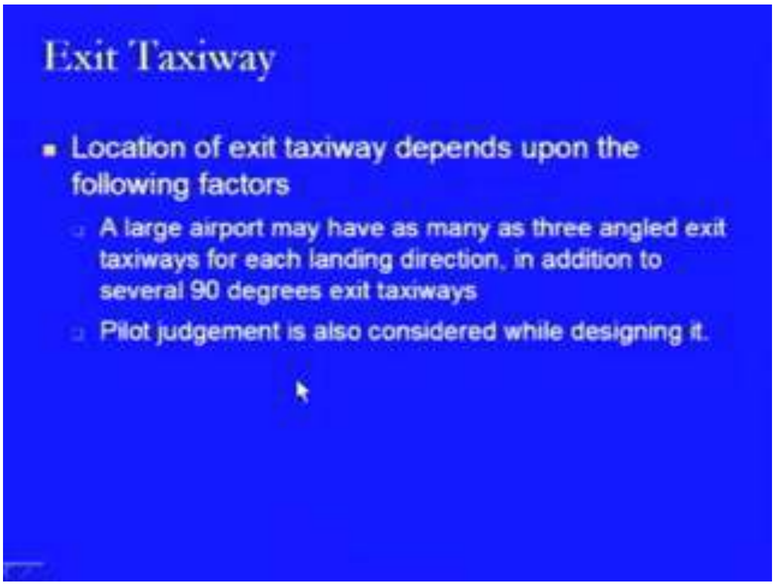

Now, further there is another factor like we have to look at the size of the airport and if there is a large airport, then there may be as many as three angled exit taxiways for each landing direction. In addition this will be there with respect to the several 90 degrees exit taxiways. So, it depends, means if it is going to be used by a large number of aircrafts and the frequency of their landing is much more, then in that case we require a number of taxiways and these taxiways, the exit taxiways we will provide it. There may be the angled taxiways provided and the 90 degree taxiways being provided. So, it is a combination of these which needs to be provided. What it says is that other than the 90 degrees exit taxiways which have been provided, there should be three angled taxiways for each landing direction.

Now the three angled taxiways will be spaced at different distances along the runway strip, so that they can take care of different types of aircrafts which will be landing with respect to the propulsive power with them and the efficiency or the fastness or rapidity with which those aircrafts can be taken away from the runway strip towards the main taxiways. While designing these exit taxiways or locating these exit taxiways, another factor which is also taken into consideration is pilot judgement

At times, the pilot judges for themselves that they have raised the speed by which they can now take a turn and can move towards the taxiway and so, after what particular time interval that is being felt on the basis of that way also the exit taxiway can be located along the runway strip.

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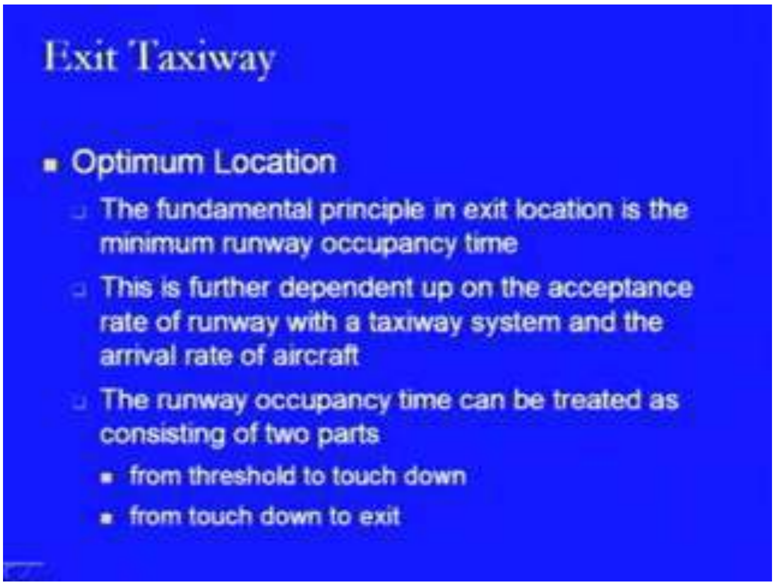

Now, once we are looking and once we are talking about the location of any exit taxiway along the runway strip, then the one thing which can be looked upon is the optimum location of that exit taxiway and in this case, the fundamental principle remains is that it should be having the minimum runway occupancy time and this is what we have just discussed before also when we started our this lecture. What it wants to say is that, as we have discussed before that the runway should be occupied for as lesser time as possible for landing. So, that remains the fundamental principle. So, we have to locate it such way that the delays are not there.

Further, it is dependent upon the acceptance rate of the runway with a taxiway system and the arrival rate of the aircraft. These are some other factors which govern whether we are having the optimum location or not. What it tries to say is that there are two things which are happening. One is that the runway system is having the arrival rate of the aircrafts. On the basis of the number of aircrafts which are going to land on that airport, there will be a specified arrival rate at which these aircrafts will be coming and then, there is another rate which is known as the acceptance rate of that runway.

Acceptance rate of that runway means that whether the runway is in position to take any aircraft which is approaching this airport and this is obviously going to be dependent on the overall capacity of the airport and the provision of the taxiways by which the runway becomes empty and when there is no other aircraft from the runway strip, then the next aircraft can utilize that for landing. So, therefore the acceptance rate of the runway strip and the arrival rate of the aircraft on the airport, these are the two things which will be governing the occupancy time and the optimum location. The runway occupancy time, then in that case can be treated as consisting of two parts. One is that from the threshold to the touchdown and another is from the touchdown to exit. That is the two main constituents of computing the runway occupancy time.

As we have discussed that an aircraft, if this is the runway strip and then, the aircraft is landing from this side, so this is the end of the runway strip. So, that is the threshold and if the aircraft is crossing this threshold and is touching the runway strip somewhere, so how much it has taken, so as to touch this runway, this particular touchdown point, so that is one of the time periods and then, once it has touched here and there is an exit taxiway being provided here, so how much time it takes to reach from this touchdown point to the exit taxiway, so that it can take a turn around and come out of the runway strip. So, in that sense the total occupancy of this runway strip will be constituting of two components.

One is the time being taken between threshold and touchdown point and the other is the time being taken from the touchdown point to the exit taxiway, exit condition. So, here it is going to be controlled by the speed with which the aircraft is crossing the threshold and here it is going to be controlled by the touchdown speed and the speed of the exit. So, these are the two speeds which will be there. Here, it is speed from threshold to touchdown, so they will be taking three speeds into consideration in that sense.

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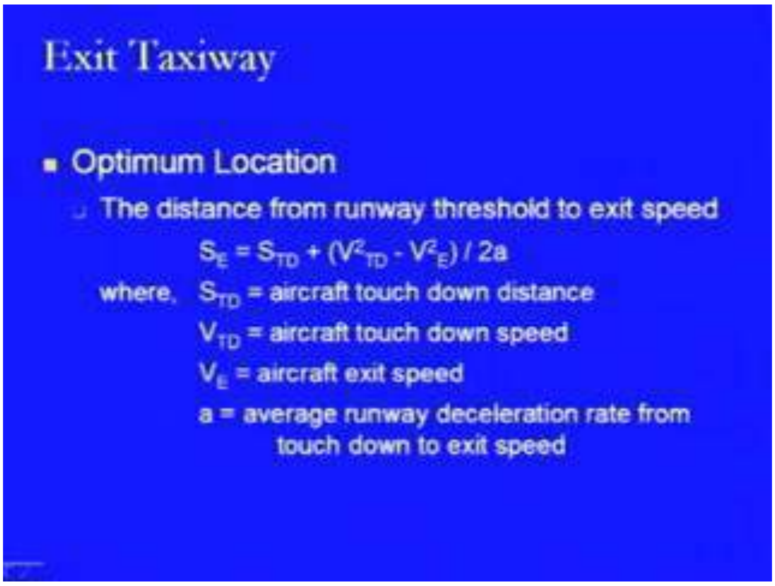

So, if we want to compute the distance from the runway threshold to the exit speed condition, then it will be given by the value S E equals to that is the distance for the exit condition or the distance for the exit taxiway will be equals to S TD, where S TD is the aircraft touchdown distance. That is once it has crossed the threshold and touches the pavement at some point and within that particular, those two points whatever is the distance being covered that is S TD plus it is V TD square minus V E square divided by 2 a. So, here this V TD, V TD is the aircraft touchdown speed, the speed at which it is touching down the pavement surface and V E is the aircraft exit speed at which it is coming out of the runway strip and this a, this is the average runway deceleration rate from touchdown to the exit speed.

So, on the basis of this value, so if this is known to us depending on the speed between this is the aircraft touchdown distance that is the distance being known most of the time, because this is defined that for this type of an aircraft, it is going to touch at this position based on its flight path and based on its speed at which it is crossing the threshold. So, that is this known generally and therefore, this value can be taken directly. Otherwise, this can also be computed on the basis of the speed of an aircraft at the threshold point and the speed of the aircraft at the touchdown point. So, with respect to those two speeds, we can compute the value.

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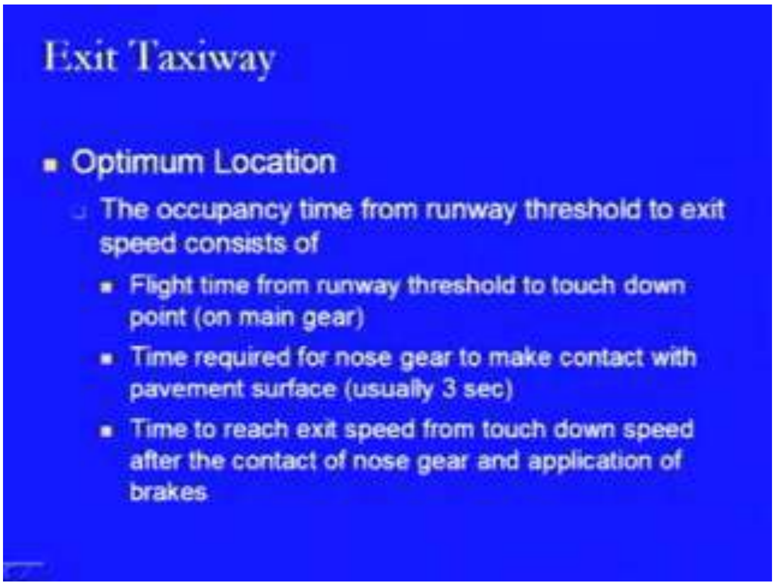

Now, this occupancy time, which we have been discussing, from the runway threshold to exit speed consists of the flight time from the runway threshold to touchdown point. Because, here now if we are interested to find out the time in the, just previously what we have seen is the distance which is being moved and that distance probably is the overall distance which is required for locating the exit taxiway. So, after reaching that particular distance, then exit taxiway can be provided at that location and which will be probably the optimum location for that aircraft.

Now, another thing which we are interested in is to minimize the occupancy time and in that sense it is going to be consisting of like the flight time from the runway threshold to the touchdown point. That is one aspect as we have discussed. Another thing is the time required for the nose gear to make contact with the pavement surface, because when it touches down the pavement, the aircraft then at that point it is the main gears which are provided below the wings. So, first of all those main gears touch the ground and once they have touched the ground, then after that slowly the nose gear touches the ground. So, there is some gap between this whole movement and this is usually 3 seconds. So, it means we have to take this 3 seconds into consideration and then, there is a time to reach the exit speed from the touchdown speed. So, there is a change from touchdown speed to the exit speed, where the exit speed is lower than the touchdown speed and that is happening after the nose gear has contacted the pavement surface and the brakes have started being applied. So, in that particular condition then we are looking at this change over.

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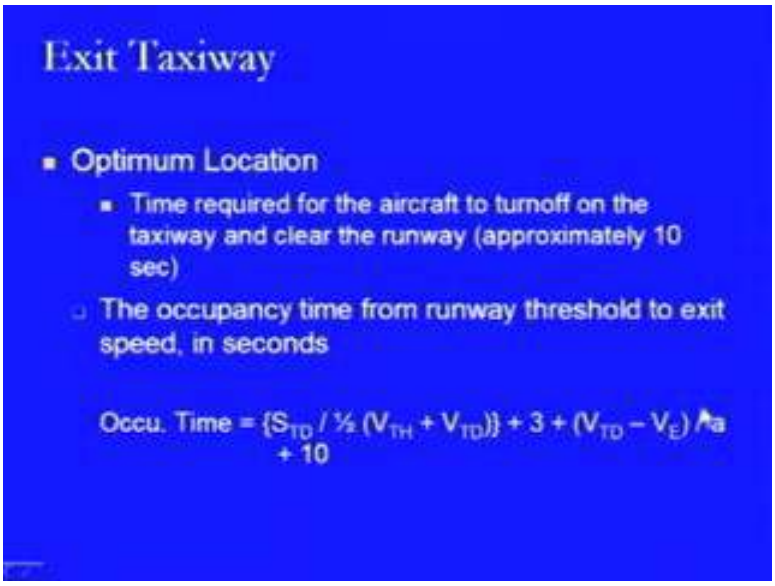

Another is the time required for the aircraft to turnoff on the exit taxiway and clear the runway. Approximately this is taken as 10 seconds. So, we have two constant values - 3 seconds and 10 seconds and then, in between those we have a certain time period, which needs to be computed on the basis of speeds. Therefore, this runway time from runway threshold to exit speed in seconds can be given by this occupancy time equals to S TD divided by half of V TH plus V TD and this whole has been added to 3 seconds that is the time which has been taken by the nose gear to touch the pavement surface plus the change in the speed from touchdown to the exit that is V TD minus V E divided by a. That is the de-acceleration speed, because the brakes are being applied, so as to reach this value of V E plus 10 seconds being given, so that the aircraft can take a turn around or turnoff and can come towards the taxiway. So, that is the overall time period which is to be considered and this time is the occupancy time of any runway strip and this needs to be minimized.

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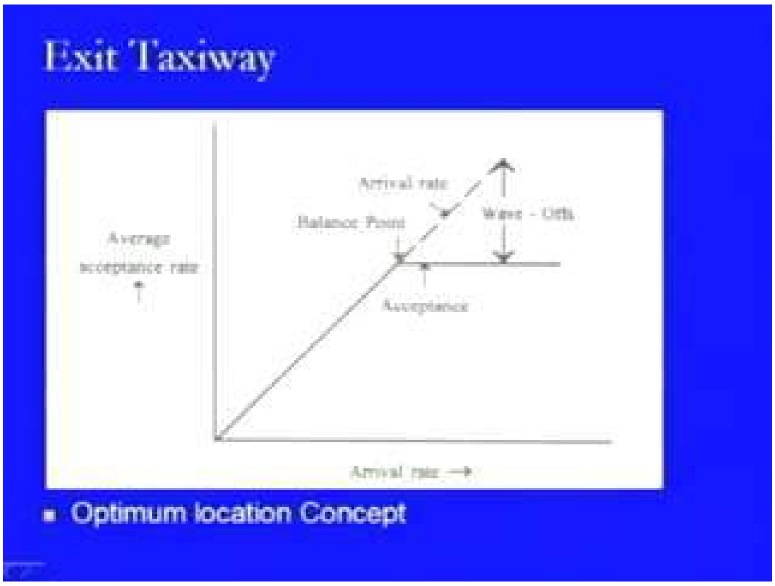

Now, here we are looking at the concept of this optimum location concept which, in the starting when we were discussing about the various factors, we have come across that they are two different types of rates which govern that how we can find out the optimum location. Here those rates are like the average occupancy rates, acceptance rate and the arrival rate. So, this arrival rate is the rate at which the aircrafts are reaching any airport and this acceptance rate is related to the runway strip with which it is being able to accept the aircraft for landing.

Now, so far the arrival rate and the acceptance rate, both are same. We will get a curve something like this. So, this is the curve, this is a straight line profile, which shows and which is moving at 45 degrees. So, this shows that whatever is the rate, the aircraft is being accepted in this system. But then after sometime, after some particular rate the condition will come, where in the arrival rate will remain, but the runway strip is not in a position or the overall airport is not in a position to accept further aircrafts.

It means, now at this particular position, though if both the things would have remained same, then this should have been the curve. But here, now because that is not the condition, so the arrival rate remains the same. That is it is coming with the same rate still as like this, but the acceptance has reached the saturation point and therefore, there is no further possibility of accepting any other aircraft on this airport and therefore, it becomes constant like this. So, at this point where it becomes constant, where still the arrival rate is increasing, then this point is known as the balancing point. That is the aircraft, this airport is in a position to accept the number of aircrafts which are going to be defined by this point of intersection or this point of change over in the value of acceptance rate, where the acceptance rate becomes constant. So, this is the, this is going to define the overall capacity of any airport in this particular way.

Now, here when the arrival rate is still there, that means there are still the aircrafts which are coming on, but they cannot be accepted, so therefore there is going to be a difference between the two values. That is the acceptance rate and the arrival rate and this value is known as wave-off, means these are the number of aircrafts which needs to be turned away from the airport or probably they have to be told to keep circling at the top of the airport, so that as soon as they have, airport has the space, can accommodate any more aircraft, then they will allow one of them to land and that is how it will go on.

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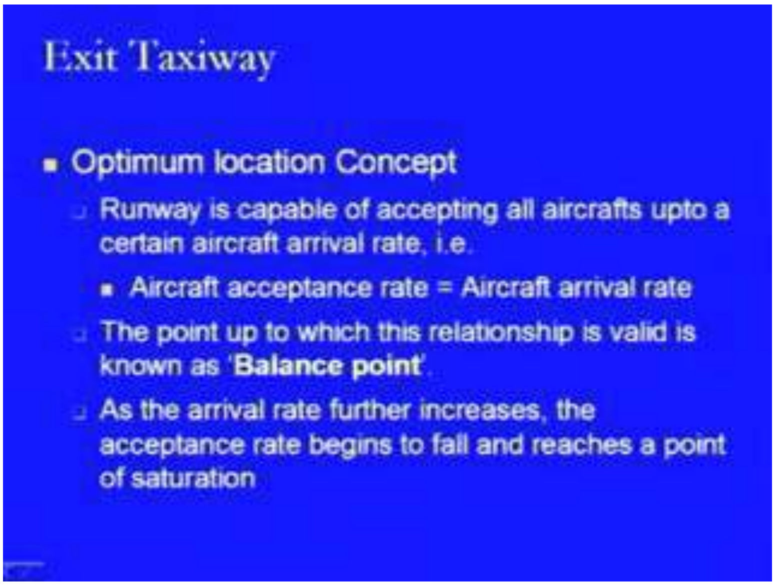

So, in this case the runway is capable of accepting all the aircrafts up to a certain arrival rate. That is if these two rates are same, then this particular point at which this relationship becomes valid or up to which this relationship becomes valid, is known as the balancing point, that already we have seen in the figure. Now, as the arrival rate further increases, the acceptance rate begins to fall and it reaches a point of saturation.

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So, after this point of saturation, then whatever aircrafts are coming after that, as I have told you, they need to be waved off and therefore, the waved off is the condition when the aircraft arriving at an airport does not complete landing, because the runway is occupied at the time the landing is to be made. So, that is the situation on any of the airport and this happens at number of times, if there are metrological problems associated at that airport. Now, this exit location of the taxiway is to be oriented such that, it yields the highest possible rate of acceptance and if we can orient in this form, then this condition is known as optimum location. So, that is how we can locate the optimum location of any exit taxiway.

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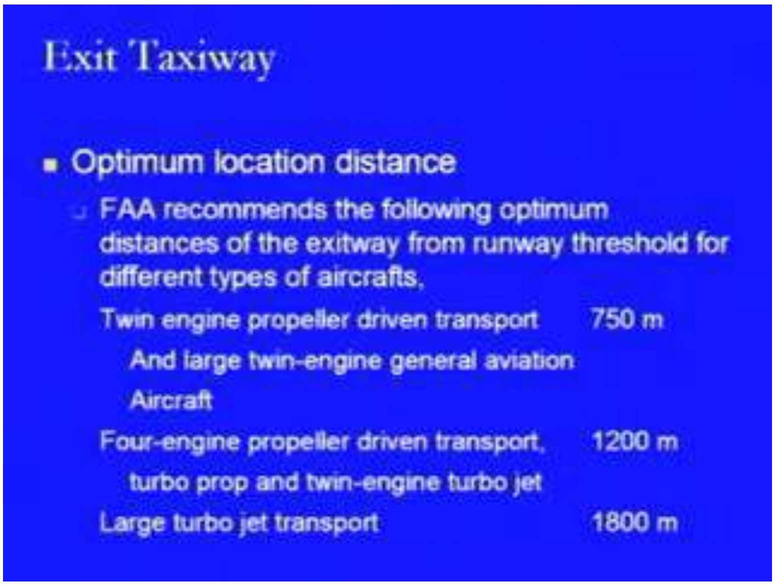

Now, within this exit taxiway, FAA recommends that the following optimum distance of the taxiway from runway threshold can be taken up depending on what type of aircraft is going to use any airport. Like in this case if there is twin engine propeller driven transport aircraft with the large twin engine general aviation or aircraft and these are the two types of the aircrafts if they are there, then as per FAA the optimum distance of the exit taxiway from runway threshold is 750 metres. Whereas, if there is four-engine propeller driven transport aircraft or Turbo prop or twin-engine turbo jet, then in that case it requires 1200 metres as distance, whereas if it is a large turbo jet transport aircraft, then it requires 1800 metres. So, as the size of the aircraft, as the propulsive power of the aircraft is increasing, keep on increasing, then this distance also keep on increasing.

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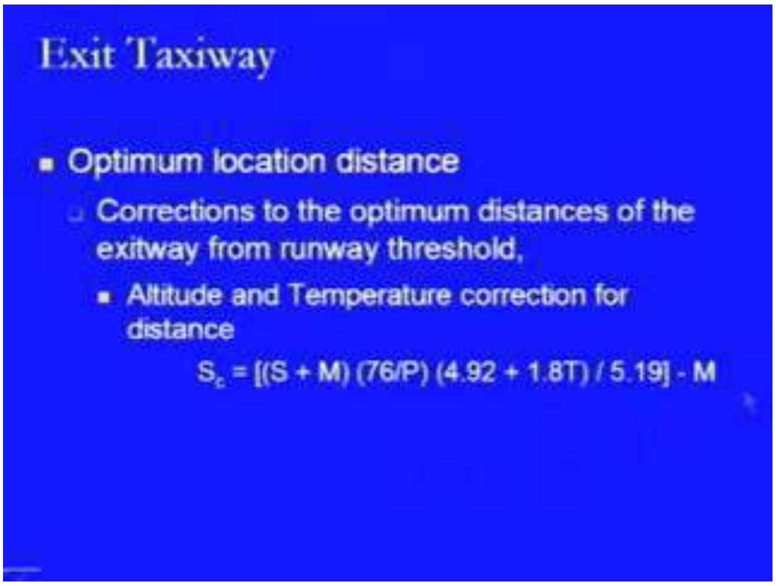

So, in this case, we look at, there are certain corrections which needs to be provided for the optimum distance of any exit taxiway and one such correction is for the altitude and temperature and this is given by this equation as S c. That is the correction for the distance S equals to S plus M multiplied with the 76 divided by P and it is further multiplied with 4.92 plus 1.8 times of T and it is here divided by 5.19 and then the whole value, from whole of the value M is subtracted that is minus M.

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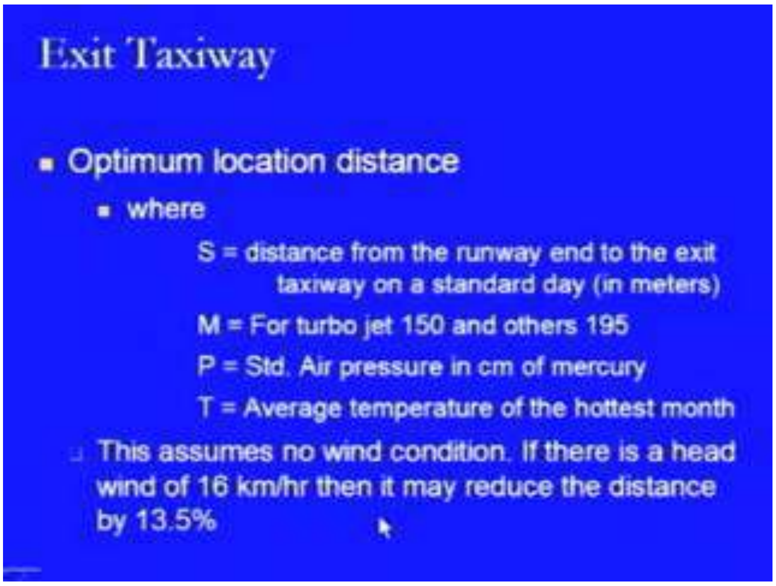

Now, whatever these abbreviations which have been used here, we look at those abbreviations and they are S is the distance from the runway end to the exit taxiway on a standard day in metres, M is 150 for turbo jet and for others it is 195, P is the standard air pressure in centimetres of mercury, T is the average temperature of the hottest month. This assumes that there is no wind condition means there is no wind blowing. If there is a head wind of 16 kilometres per hour, then it is being observed experimentally that it may reduce the distance by 13.5%. So, the effect of wind if it is there, then it can be taken in this form.

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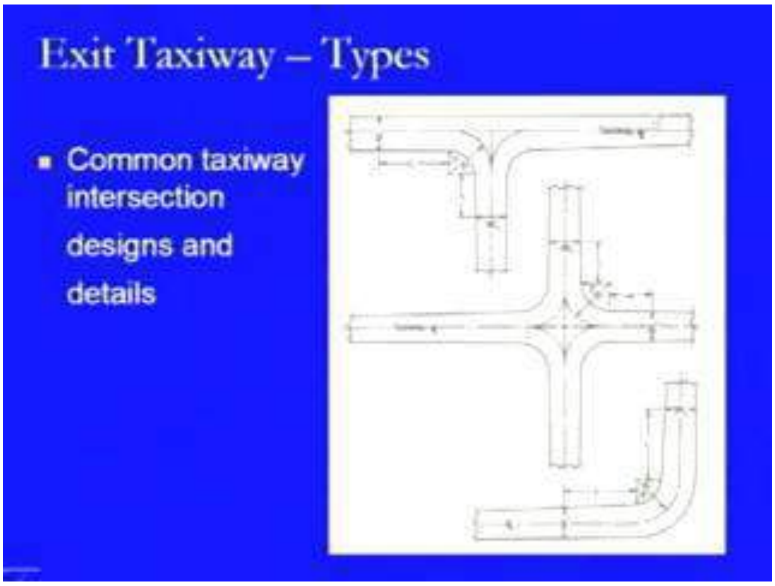

Now, some of the common taxiway intersection design and the details have been shown in this figure, where this is a T sort of a junction. We have the taxiway being provided here and this is the exit taxiway being provided. So, we have a curve from this side as well as from this side and this is the width of the taxiway, whereas this W T is the width of the exit taxiway and here, this is a straight portion and then, after that the flaring starts and goes up to a length L, whereas here also up to a length L, then we have a point of rotation and that is this defines the radius R.

So, similarly this a condition where there is a crossing being provided between a taxiway and an exit taxiway and it is taking the traffic further. So, these are the two or the two taxiways are crossing each other. So, similarly all the figures have been shown here. Here it is in the form of a L taxiway that is it is sort of a turning the end of say, the runway strip and that is how we can see the two type difference.

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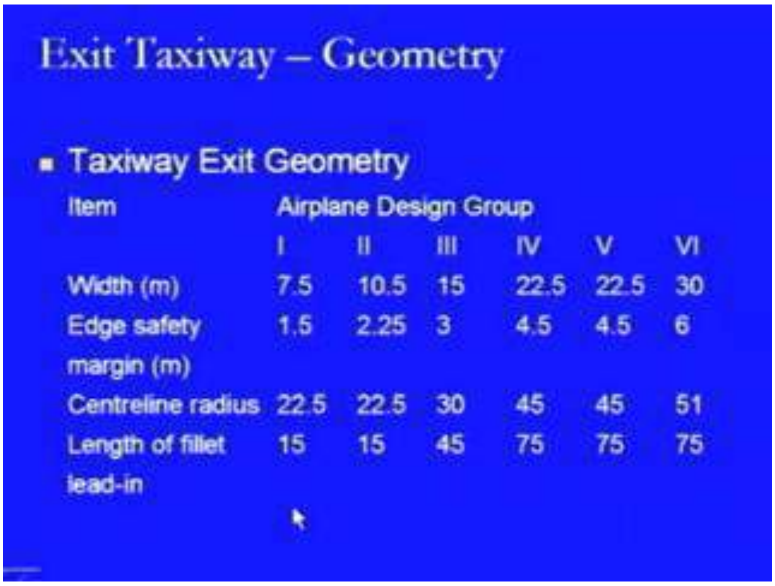

Now, another thing which is related to the exit taxiway is its geometric values and these geometric values are defined by the airplane design group and here, what we see is that the width ranges from 7.5 metres for a design group category I to 30 metres for a design group category of VI, whereas the edge safety margin again in metres varies from 1.5 metres at minimum to 6 metres at the maximum. Then, there is a centreline radius which varies from 22.5 metres for category I to 51 metres for the highest category that is VI. Length of the fillet also varies and initially it is 15 metres and then, for category III it is 45 metres and for the rest of the big categories it is 75 metres.

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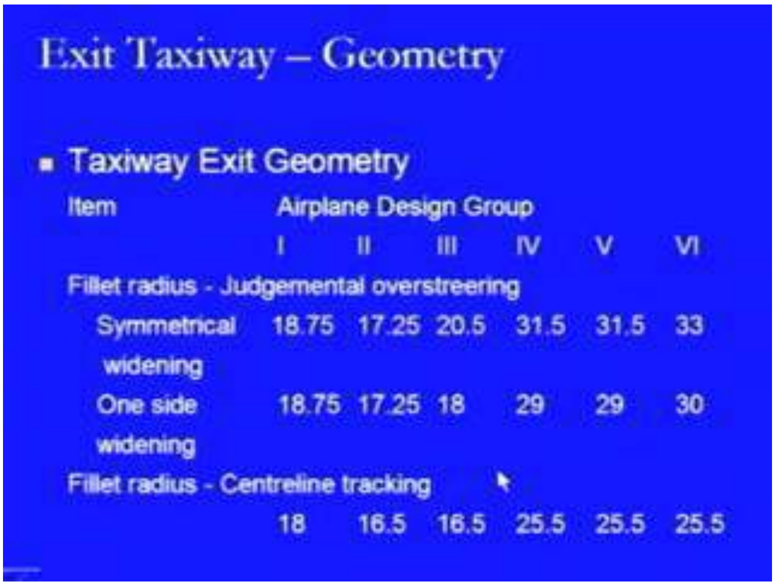

Then, further there are some more things like the fillet radius and this fillet radius can be computed on the basis of the type of the steering which is like judgemental oversteering and in this case, if it is symmetrical condition, it varies from 18.75 metres to 33 metres, again for the airplane design group ranging from category I to category VI. Then, if there is a widening and if there is one side widening, in this case it will be 18.75 metres to 30 metres. So, there is some variation in these values, a small difference and the fillet radius in the case of centreline tracking that is the nose of the aircraft is moving along the centreline, then in that case the value varies from 18 metres to 25.5 metres.

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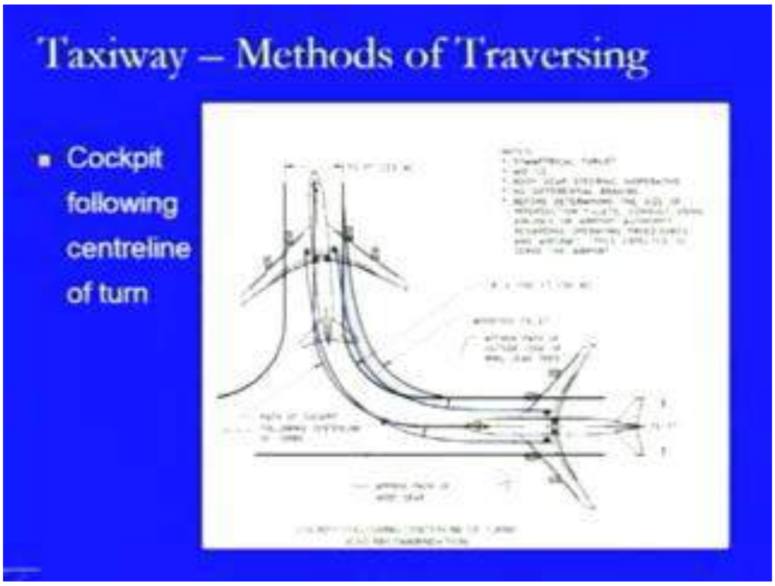

Now, we come to the methods of traversing. We have seen of course these methods of traversing before also, now we are looking at the same thing here that is the cockpit is following the centreline of the turn. That is this nose is moving along the centreline, so what we have seen is that it moves like this. But, while doing this way, there is a slight tilting of the aircraft towards the inner side and what is being observed that in this case, this wheel path will go away from the inner edge of the pavement surface. That is why the fillet needs to be provided with the full strength, so that it can take the load of the aircraft which is moving in this form. So, this is one method which is also recommended by ICAO.

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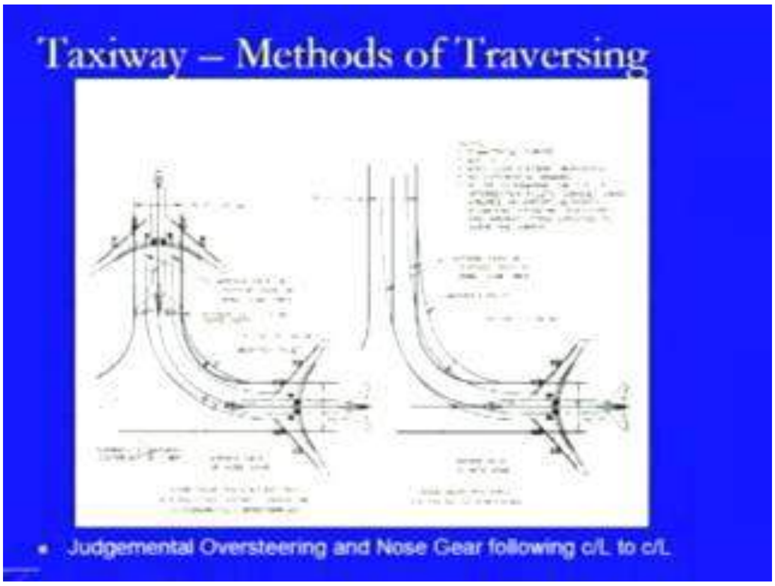

Whereas, there is another method like the judgemental oversteering method. In this judgemental oversteering method, this nose is not going along the centreline of the strip, whereas it goes a little away, so that this inner wing of the main gear it remains well within the edge of the pavement surface and therefore, we require a smaller size of the fillet in this case, if this type of method is being used. But, the nose is going a little away and it will come back to the position, after certain, once this curve is being negotiated. So, here there is no tilting of the aircraft and the aircraft remains within the same central position. So, that is another type of condition.

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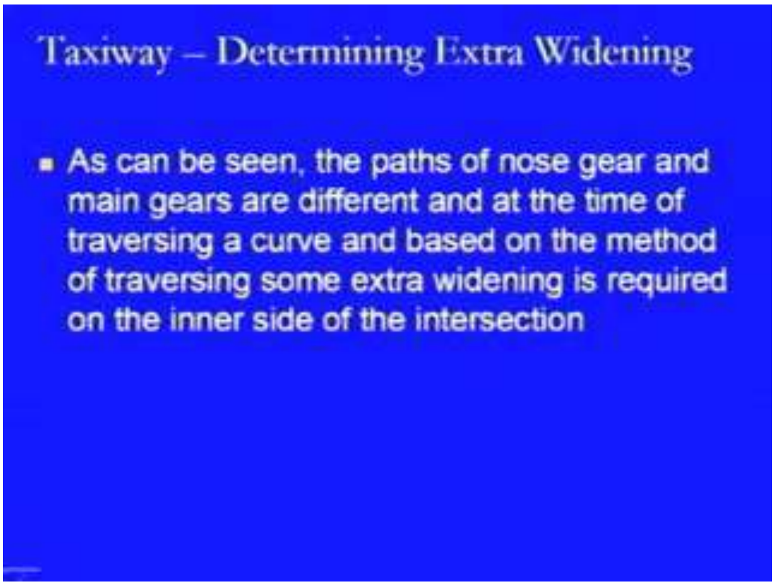

So, in these cases we have to determine that by what particular value the extra widening needs to be provided or the fillet area needs to be provided. So, what we have seen is that the path of nose gear and main gears are different and then, at the time of traversing a curve and these are therefore, there is a method of traversing wherein some extra widening is required on the inner side of the intersection.

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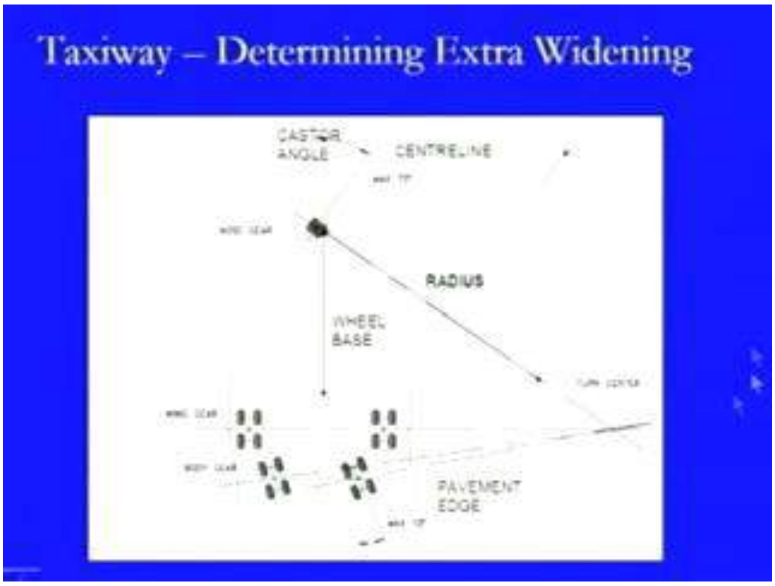

So, in that case, here we have this, another figure, where we are trying to show the same thing. This is the nose gear and this is the centreline. This is going along the centreline and these are the main gear threads and these are the body gear threads being provided behind those one. So, what we can say is that they are taking their own different turning conditions. So, this is the normal condition, they are going straight. This is the steering in this direction at an angle of some value that is known as castor angle and this castor angle can be at the maximum 70 degrees.

Now, the turning is going with respect to here. So, this is the point of turning. So, therefore this is the radius at which this turning is taking place and this is the pavement edge within which this remains and here, again in this particular side, the body gears that they are taking a turn in this direction and they will be coming towards this directions. Here, this angle can be at the maximum 13 degrees. So, the distance from this point to this axis on which these two wing gears are that is the wheel base which will be available at this condition. So, we will be using this wheel base, so as to determine that in what particular position the curve will be negotiated by the nose gear and by the main gear.

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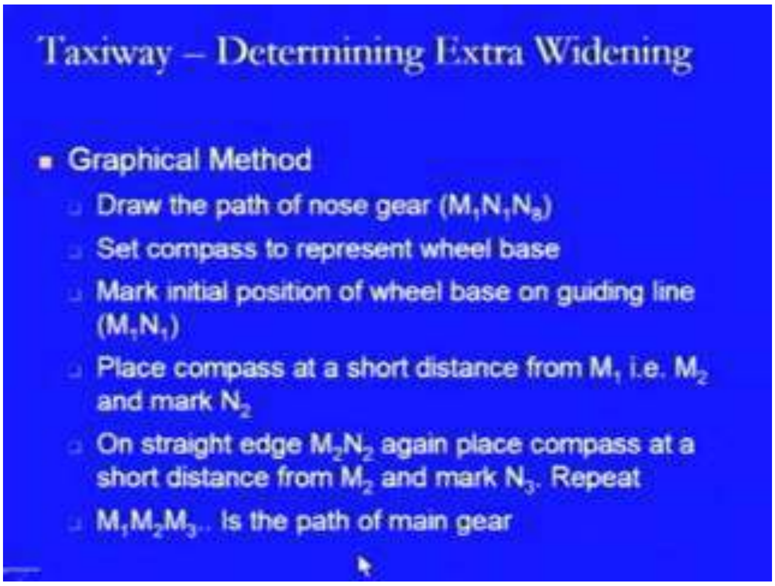

So, there is a graphical method of doing that and in that graphical method, first of all we draw the path of the nose gear, which say, being defined as M 1, N 1, N 8; N for nose gear, M for main gear. Then, what we do is that we set our compass to represent the wheel base which we have seen in the previous figure and once we have got this distance, then we mark the initial position of the wheel base on any guiding line and say that is M 1 N 1.

So, whatever is the path which we have, from this point M 1 we take this much distance and just make a point on this curve. So, that will be M 1 N 1 position. Then, once we have done this, what we do is that we come a little lower than the value M 1, say to position M 2, which is lying on the same curve and then, we mark another location N 2. So, that is M 2 N 2 location. So, likewise we keep on going and again we place a compass at a short distance of M 2 and mark N 3 and we keep on repeating this and once we do this way, then we will be getting another locations of the points that is M 1, M 2, M 3, etc., and this particular line path will be known as the path of the main gear. So, that is how we can find out that how the paths will be differentiating.

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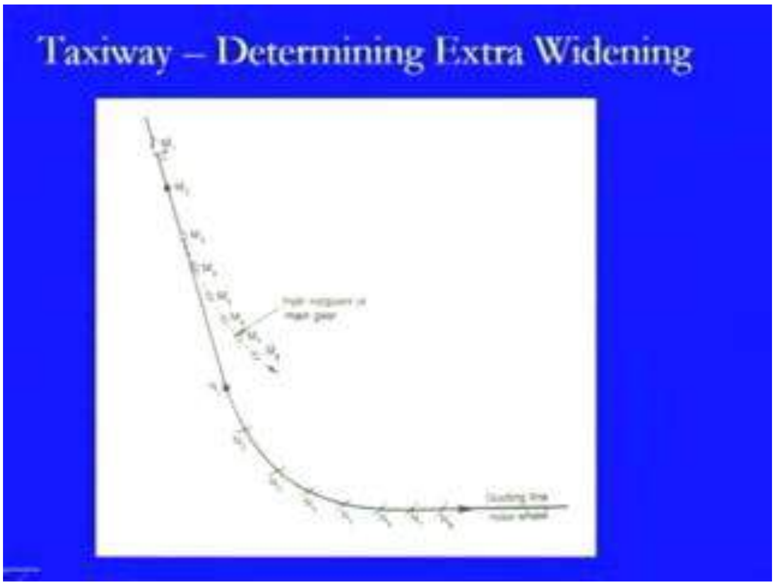

Here, we can see in this diagram that this is M 1, this is N 1 and then, this is N 8. So, this is the guiding line or this is the line along which the nose wheel will be moving. So, this is how it is going to happen. Now, the wheel base is equivalent to M 1 N 1. So, we have taken some point M 1 here and with the help of the compass, we have located the point N 1. Now, once we have done this, then we come short of this M 1 and we locate, take a point M 2 and cut it somewhere, so that we have another point N 2 at some distance here. So, that is lying on this straight and this is how we keep on going and we keep on marking the points on this side, so the distance from, like from M 8 to N 8 should remain equivalent to the distance as of the wheel base. So, whatever the path we are getting in this form, this path is the midpoint of the main gear path.

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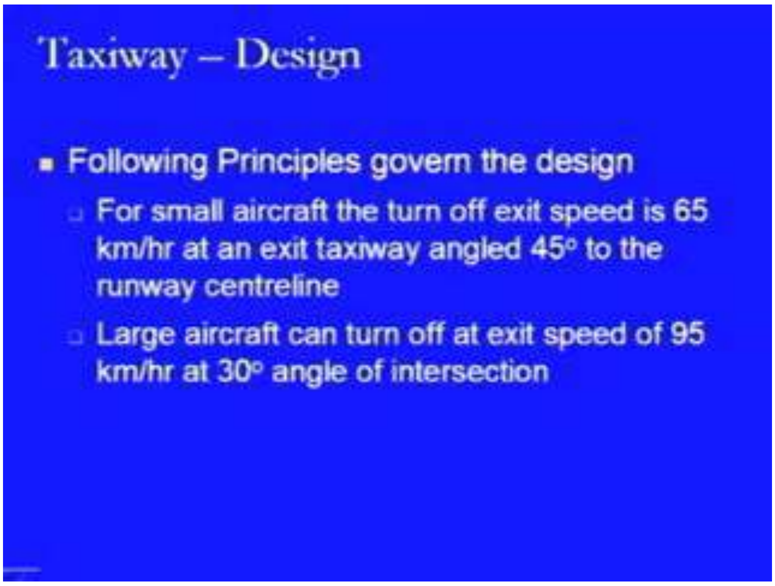

Now, we come to the design of the taxiway and there are certain principles which govern the design. In the case of small aircraft, the turnoff exit speed is taken as 65 kilometres per hour at an exit taxiway angle of 45 degrees to the runway centreline, whereas in the case of large aircrafts this turnoff speed at the exit time is taken as 95 kilometres per hour, where the angle of intersection is taken as 30 degrees. So, that is the rapid condition of the exit taxiway.

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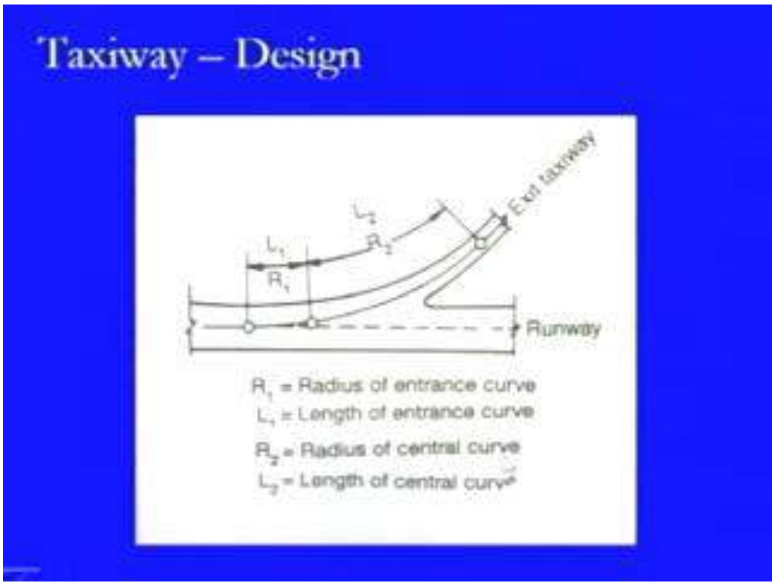

This is a diagram which shows the components which we have to design that is this is the runway. From this point it starts moving away from the runway strip. So, this is initial curve that is L 1 with the radius R 1. Then, there is another central curve which is having length L 2 and radius R 2 and it moves in this form and then after this, again it will become a straight line.

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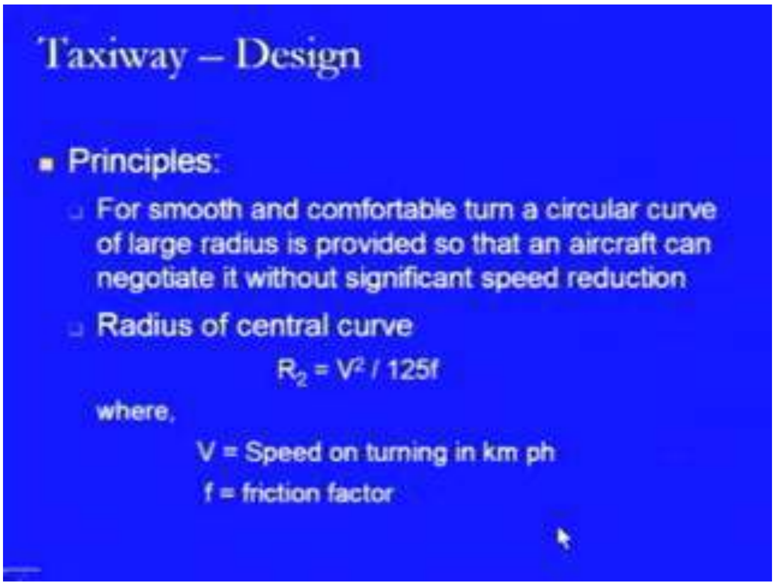

Now, another thing is that for a smooth and comfortable turn, a circular curve of large radius is provided, so that an aircraft can negotiate it without significant speed reduction. That is the thing which we have seen as another curve that is central curve with the length L 2 and radius R 2 and the radius of this one can be found out by a formula V square divided by 125 f, where V is the speed on turning in kilometres per hour that is the speed with which it is taking a turn for exiting and f is the friction factor. Usually this friction factor is taken as 0.13.

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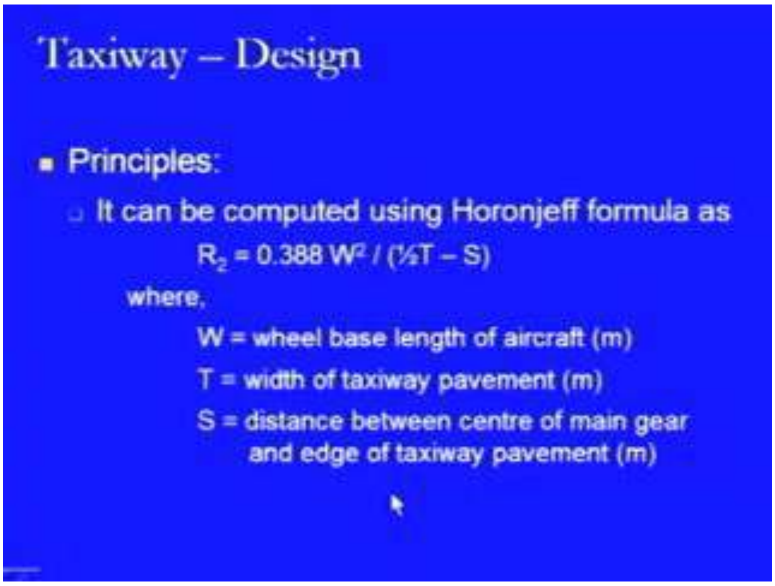

Then, this is, this R 2 value can also be computed by using the Horonjeff formula, which is 0.388 W square and this is divided by half of T minus S, where this W is the wheel base length of the aircraft in metres and T is the width of taxiway pavement in metres and S is the distance between the centre of main gear and edge of taxiway pavement, again in metres.

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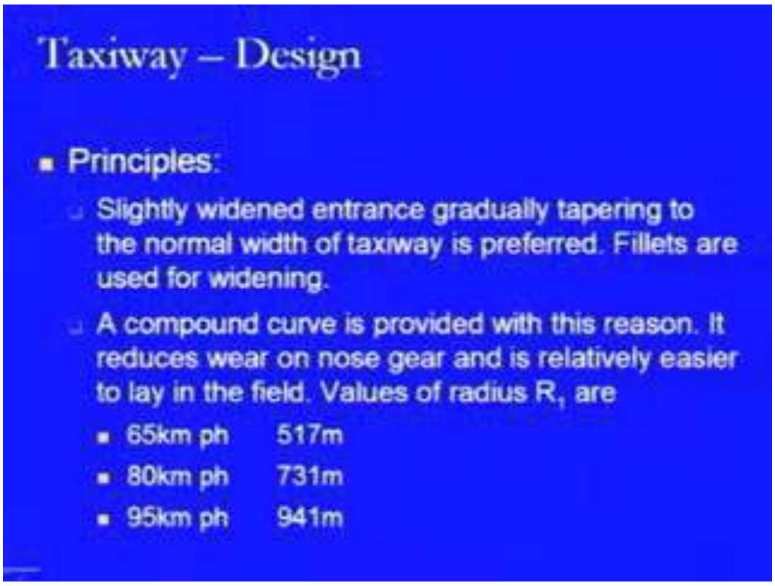

Now, there is a slightly widening entrance which is provided, which is gradually tapering to the normal width of the taxiway and this is preferred and the fillets are also used for widening. In the case of this compound curve is provided, then it reduces the wear on the nose gear and it is relatively easier to lay in the field. In this case, the value of radius R 1 that is being shown like in the previous diagram with the length L 1, here it is defined on the basis of the exit speed with which the aircraft is coming out of the runway and if it is 65 kilometres per hour, then this R 1 is taken as 5.7 metres. If it is 80 kilometres per hour, then it is taken as 731 metres and if it is 95 kilometres per hour, then this value of R 1 is taken as 941 metres.

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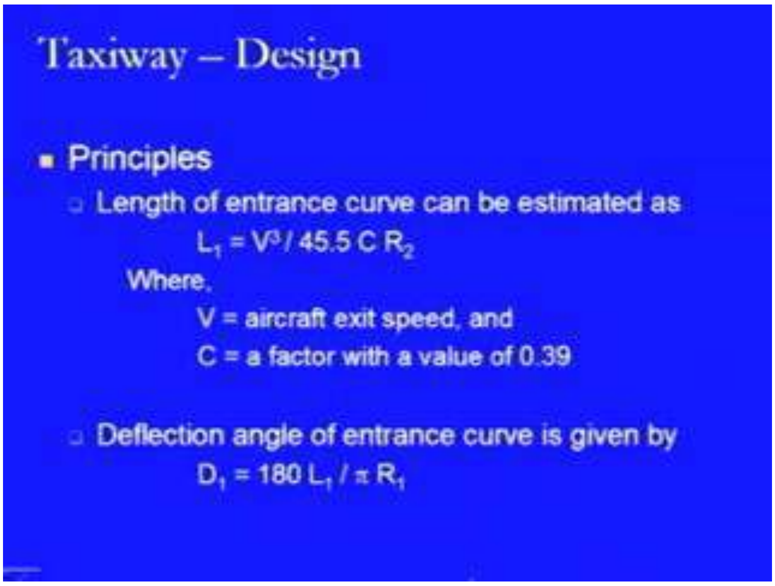

Now, the length of entrance curve is estimated as L 1 and this is V cube divided by 45.5 C multiplied with R 2. Now, here the V is the aircraft exit speed R 2 is as computed previously that is the radius of the central curve and C is a factor which is normally taken as 0.39. Now, the deflection angle for the entrance curve that is for the initial curve of the compound curve is D 1 and this can be computed as given by this formula like 180 into L 1 divided by pi into R 1 and we know the R 1, we know L 1, so we can compute the value of D 1.

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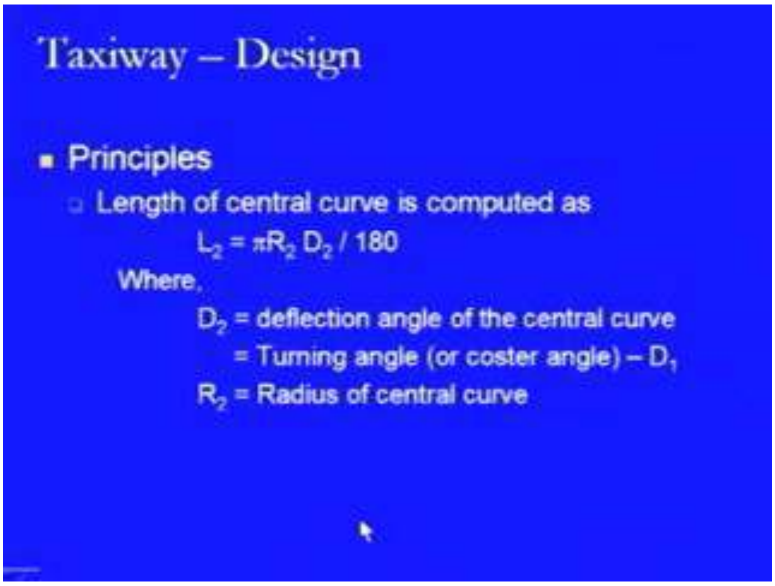

Now, the length of the central curve is computed by the formula pi into R 2 into D 2 divided by 180. So, these are all on the basis of the properties of the circular curve only. Now, here D 2 is the deflection angle of the central curve and this can be computed by taking the coster angle or the turning angle and subtracting D 1 from this value. R 2 is the radius of the central curve.

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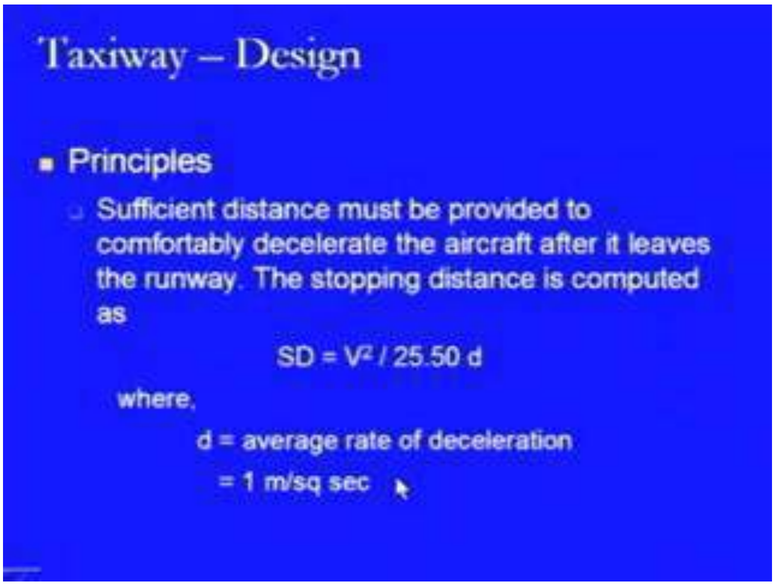

Then, there is a sight distance which needs to be provided and this sight distance defines the stopping distance, basically because this is the point up to which the aircraft can be stopped without any accident taking place. So, therefore this governs the comfortable deacceleration rate with which the aircraft is deaccelerating and leaving the runway strip and this can be computed by the equation as shown here that is SD is equals V square divided by 25.50 multiplied with d, where this d is the average rate of deacceleration and if it is not known, then it is generally taken as 1 metre per square second. In the case of ICAO that is being defined as 1.25 metre per square second.

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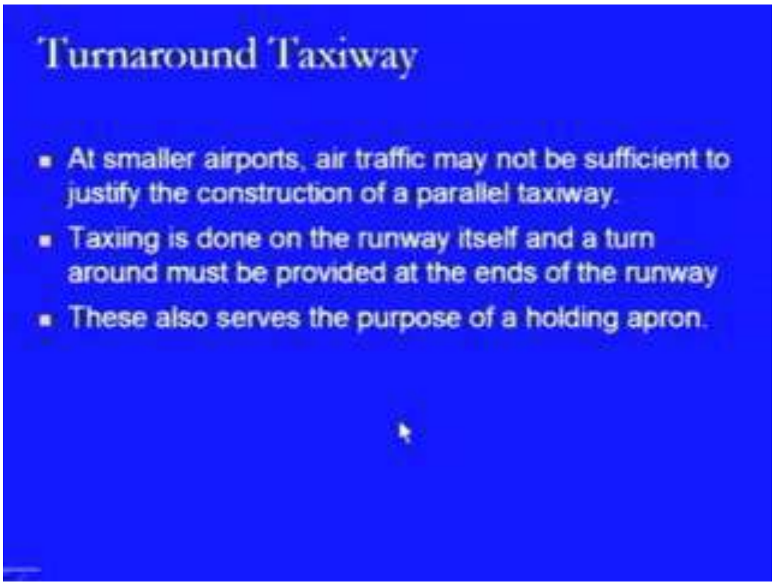

Now, in the case of smaller airports, the air traffic may not be sufficient to justify the construction of parallel runways. So, in those cases, then what we provide is the turnaround taxiway, where the taxiing is done on the runway itself and a turnaround is provided at the end of the runway strip. So, that is the condition which is termed as the turnaround taxiway. These also serve the purpose of holding apron, means this is a type of the apron which is to be provided, which we will be discussing in the coming lectures. What we can understand is that it provides the condition where an aircraft can be stored for some time period, if there is an emergency. So, that is what a holding apron is. Therefore, it also helps in the way that it can be used as holding apron.

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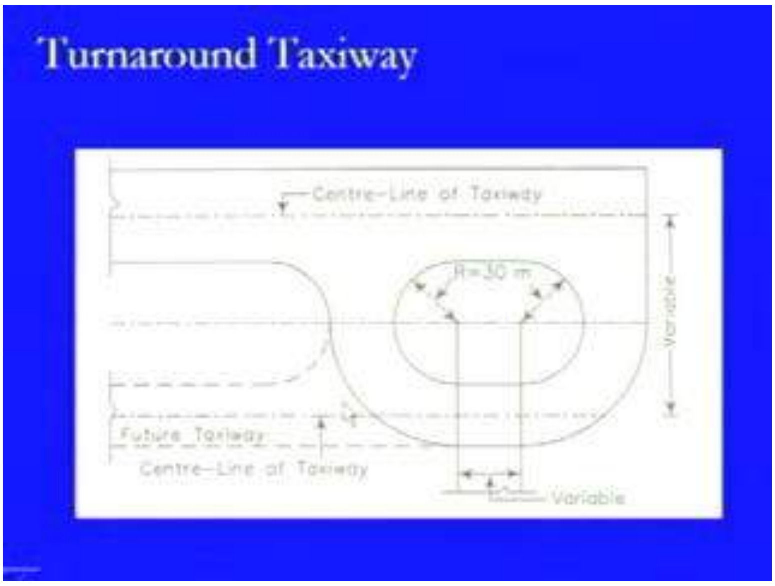

Now, here in this figure, the same thing is being depicted, where this is the centreline of the taxiway or this may be the runway strip and then here, we are providing the turning of the aircraft and the aircraft comes up to this location, it takes a turn like this, comes back, this one and then goes in this direction and gets exited. So, that is the type of the turnaround condition being provided and this distance remains variable depending on the type of the aircraft, which are going to use this type of a facility. Most of the time, these aircrafts are of smaller size, because these facilities are provided generally on the smaller airports. In future, if this is to be extended and parallel taxiway needs to be provided, then this can be extended in this direction as been shown by dotted lines.

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Now, another type of feature is the taxilane. In the case of taxilane, this is portion of the aircraft parking area here being used for access between the taxiways and the aircraft parking position. So, that is how it is defined, so as we understand that in the case of the terminal buildings, the aircrafts will be standing just in front of the terminal buildings and if the similar sort of a condition is there or there is a parking of those aircrafts at the other side, then in between these two types of parking, there will be some pathway and that particular pathway is termed as taxilane, which provides the connectivity, which provides the area through which the aircrafts can move and can access either the parking area or can access the terminal building or may move towards the taxiways.

Now, as far as ICAO is concerned, it defines this taxilane as an aircraft stand taxilane as a portion of apron intended to provide access to only the aircraft stands. That is how it defines it. It simply speaks about the aircraft distance through which the aircraft will be moving and whatever portion of the taxilane is used for that purpose is taxilane.

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So, in this photograph, a taxilane is being shown. Here, we can see that there is a terminal building on this side along with the terminal building on this side and these are the gate positions being provided, where the aircrafts can stand and the passengers can board the aircraft. Similarly is the condition on this side. We can see the aircrafts standing on this position and on this position and then, here we have the runway strip at the farthest condition, where we can see the take-off aircraft and the landing aircrafts simultaneously doing on two different runway strips and then, this is the taxiway being provided.

Here is another taxiway being provided. So, there are the parallel taxiways on which different aircrafts are moving. So, in this case, there is a connectivity being provided from these taxiways to this parking area that is this apron as well as this terminal apron. So, we have the terminal apron on these two sides and the aircraft is moving in between these two areas and this particular area is known as taxilane.

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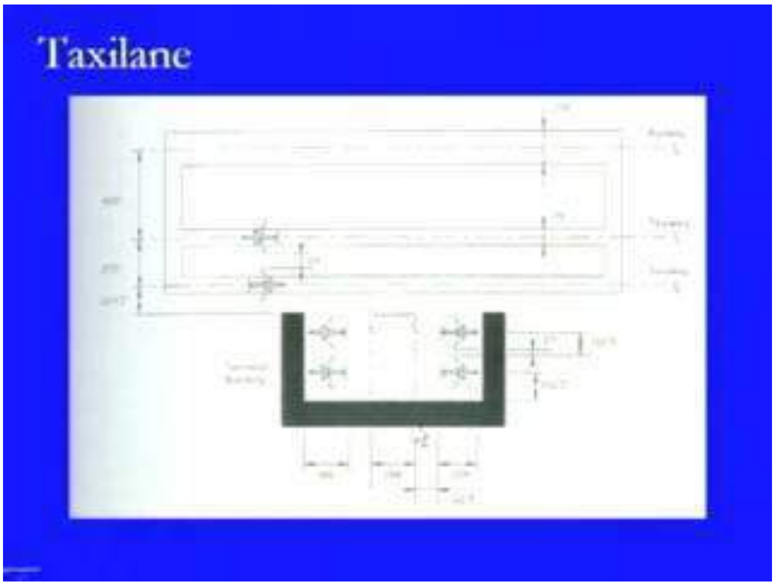

Here is another figure, where the concepts have been shown that these are, this is the runway strip and these are the two parallel taxiways being provided and as we can see that there is a unidirectional movement on these taxiways, the aircraft moving towards left on this one and towards right on this one, so as to increase the safety as well as efficiency of the airport and then from this particular taxiway, then there is a connectivity being provided to this terminal building on which the aircrafts are being, there the aircraft stand is being provided on this side and this side for boarding of the passengers, similarly on this side.

So, whatever the space is being left in the centre, so that this aircraft can come to this direction and move towards the taxiway or from this side, it can come to this direction and can take a position on the stand. This area is taxilane. So, some of the details have also been shown that what is the distances which needs to be provided here.

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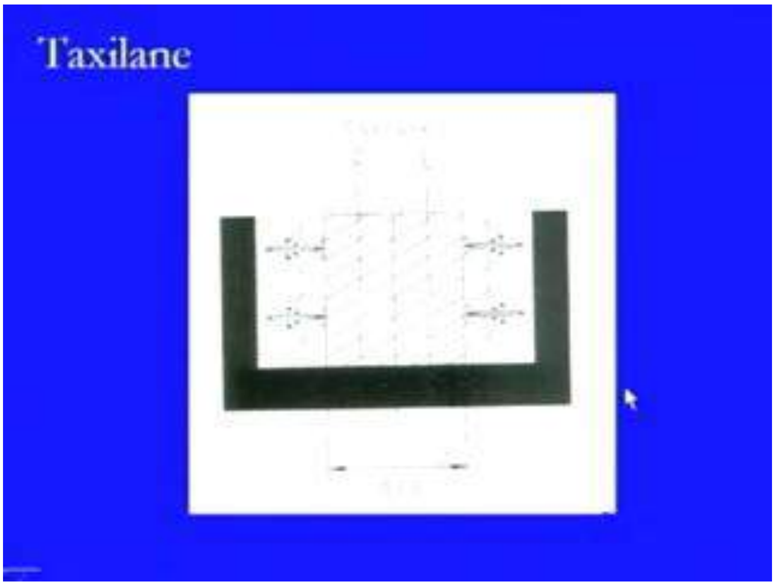

This is another close up of the same condition, where we have the taxilanes, two taxilanes being provided with their centrelines like this.

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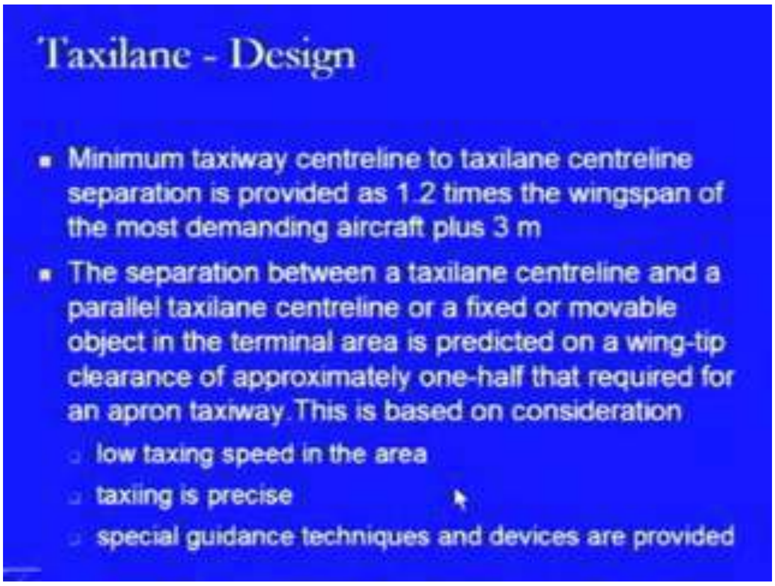

So, in this case, we have to design this taxilane. So, what we need to consider is that the minimum taxiway centreline to taxilane centreline separation is provided as 1.2 times the wing span of the most demanding aircraft plus 3 metres. So, that is how we can compute the value between the two centrelines. Then, the separation between the taxilane centreline and the parallel taxilane centreline or a fixed or movable object in the terminal area is predicted on a wing-tip clearance of approximately one half that required for an apron taxiway.

So, this is another thing which is to be considered and this is, here we have to look at the distance which is being provided in the case of apron taxiway and the clearance which is provided between the taxilane centreline and the fixed or movable object in the terminal area is half of that distance and this value is dependent on the low taxing speed in the area, the taxing is precise or not and special guidance techniques and devices which are provided for doing the taxiing.

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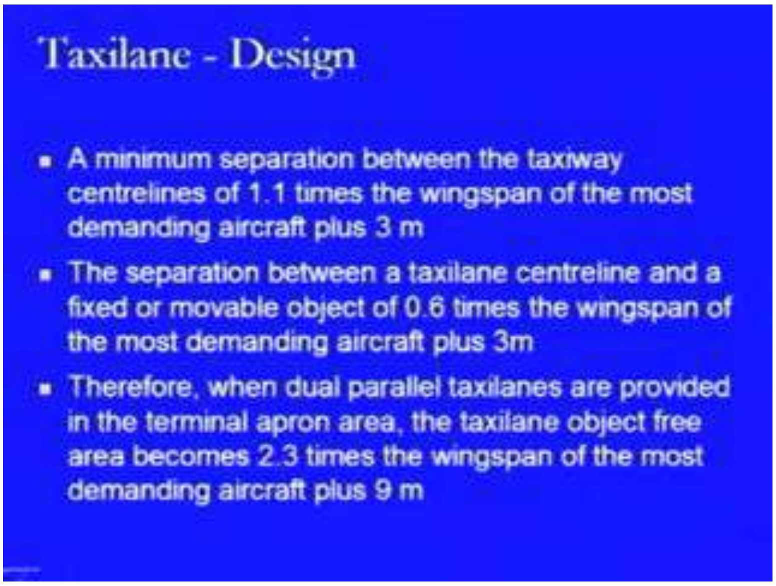


Further, a minimum separation between the taxiway centrelines of 1.1 times the wingspan of the most demanding aircraft plus 3 metres can be provided, though the desirable, as we have seen previously, is 1.2 times the wingspan plus 3 meters. The separation between a taxilane centreline and the fixed or movable object is 0.6 times the wingspan of the most demanding aircraft plus 3 metres. So, everything is going to be governed by the wingspan of the most demanding aircraft or the biggest aircraft which is going to generally utilize that lane or that airport. Therefore, when dual parallel taxilanes are provided in any of the terminal apron area, then the taxilane object free area becomes 2.3 times the wingspan of most demanding aircraft plus 9 metres.

So, that is the overall size of any of the dual parallel taxilanes will become, as being shown previously. So, 3 metres in this 9 metres is taken on the, 3 metres on the two sides plus 3 metres in the centre of the two aircrafts. So, that is the clearance being provided as we have seen previously. So, this how we can design any of the taxilane.

So, in today's lecture what we have seen is that how we can design any of the exit taxilane, so that we can improve upon the airport capacity in terms of reducing the occupancy time of any aircraft on the runway strip and we have also seen the various design factors which creates its influence on finding the value of the occupancy time or as well as finding the distance at which optimally the exit taxiway needs to be located. Along with the taxiway, exit taxiway, we have also seen the design principles and the design parameters and their computation and then, we have also looked at two specific types of conditions which are termed as the taxi turnaround taxiway and taxilane. So, we will be stopping at this point and we will be continuing with our discussions on airport engineering in the coming lectures. Till then, goodbye and thank you to all of you.

- Separation clearance
  - As per FAA, in meters

Design items	Airplane design Group					
	1	2	3	4	5	6
Taxiway Centre line to: parallel taxiway c/l	21	31	46	68	75	102
Fixed or movable objects	13.5	20	28	41	46	61.5
Fixed or immovable object	12	16	25	36	39	51
Runway Centre line	120	120	120	120	Vary	180

- Separation clearance
  - As per ICAO, in meters

Minimum separation	Aerodrome code				
	A	B	C	D	E
Taxiway centre line to:					
taxiway centre line	21	31.5	46.5	68.5	81.5
object	13.5	19.5	28.5	42.5	49
Aircraft stand taxi lane	12	16.5	24.5	36	42.5
Min wing tip clearance	3	3	4.5	75	7.5
Stand safety margin	1.5	1.5	2	2.5	2.5

- **Separation clearance**
  - Minimum separation between parallel taxiway centerline is given by
    - $S_{TT} = W + 2\,U_1 + C_1$
  - Required separation between a taxiway centerline or an apron taxiway and fixed or moveable object
    - $S_{TO} = 0.5\,W + U_1 + C_2$
  - Required Separation between a aircraft stand taxi lane and fixed or moveable object
    - $S_{ATO} = 0.5W + U_2 + C_1$

- Where,

  W = wing span of most demanding aircraft

  U_1 = Taxiway edge safety margin

  C_1 = Minimum wing tip clearance

  C_2 = Required clearance between wing tip and object

  U_2 = Aircraft stand safety margin.

Apron Marking

- Certain guidelines are marked on the apron to help the pilots in maneuvering the most critical aircrafts.
- Generally they are related to the path to be traversed during parking in or out operation near terminal location or nose etc.
- Yellow colour is used at such locations
- It should be fuel resistant as aprons are likely to be subjected to fuel spillage.

Apron Markings

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


STOP

Taxiway Marking

- Center line of taxiway consists of 15cm wide continuous stripe of yellow colour
- At intersection with runway end, the centerline of the taxiway is terminated at the edge of the runway
- At all other intersections with the runway, the centerline of the taxiway extends up to the centerline of runway
  - At other intersections with runway it will reach up to the centerline of runway and joins there.

- At the taxiway intersection, the centreline marking of the taxiway continue through the intersection area
- For taxiway intersection where there is a need to hold the aircraft, a dashed yellow holding line is placed perpendicular to and across the centreline of both taxiways

RUNWAY LIGHTING:

- After crossing the threshold, the pilot must complete a touchdown and roll out on the runway.
- The planning of runway lighting is carried out in such a way that the pilot gets enough information on alignment, lateral displacement, roll and distance.
- The lights are so arranged so that they form a visual pattern which the pilot can interpret easily.
- During night landings, flood lights were used in olden days. But now runway edge lights are adopted.

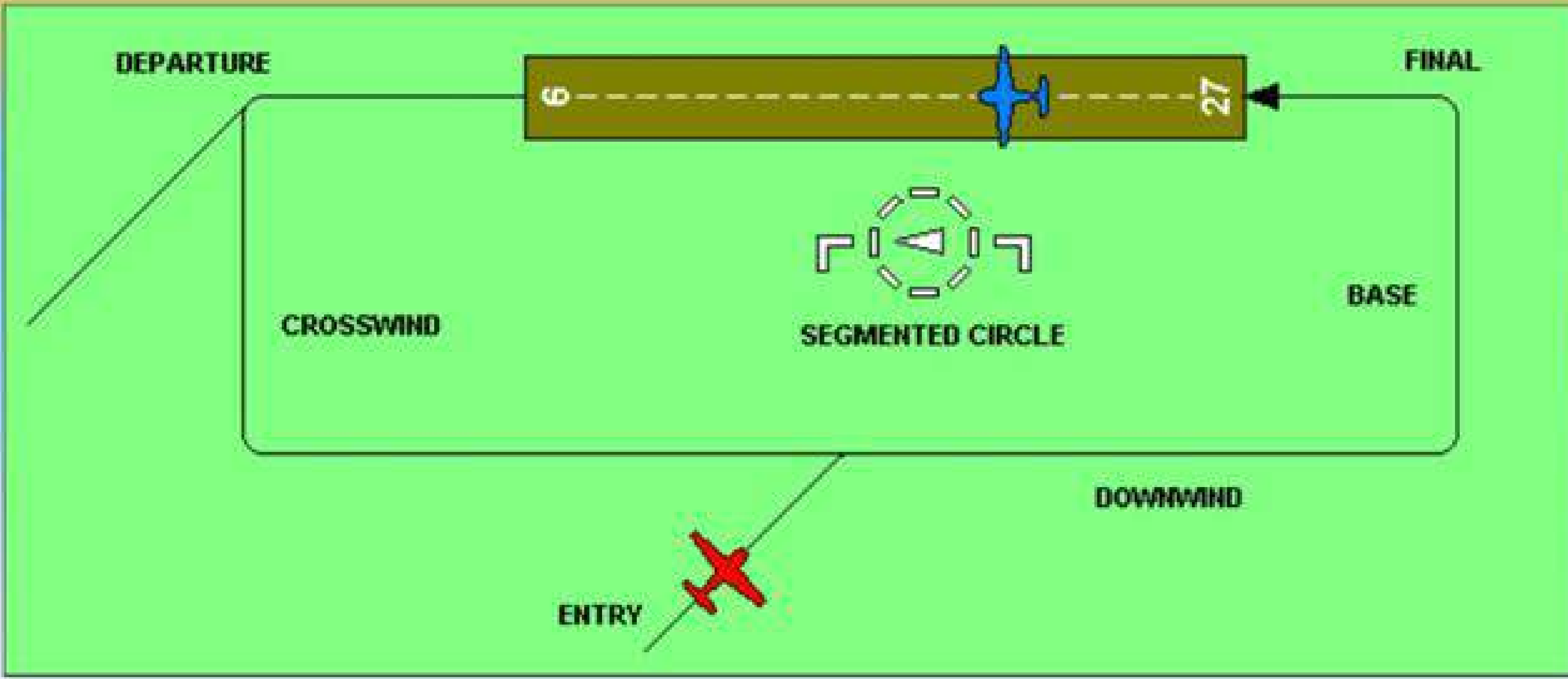
- <u>Narrow gauge pattern</u>- the most precise runway alignment which is widely used.
- It makes use of centre-line and touch down zone lights for operations in very poor visibility.
- <u>Black hole effect:</u> As the pilot crosses the threshold, and continues to look along the centre-line, the principal source of guidance, namely, the edge lights has moved far to each side in the peripheral vision. As a result, the central area appears black and the pilot is virtually flying blind for the peripheral reference information.

TAXIWAY LIGHTING:

- The pilots have to manoeuvre the aircrafts on a system of taxiways to and from the terminal and hangar areas either after landing or on the way to take off
- The taxiway system is much complicated on large airports and therefore it is necessary to provide adequate lighting at night and at daytime when the visibility is very poor.

taxiways:

- For normal exits- centreline terminated at the edge of the runway.
    - At taxiway intersections, the lights continue across the intersection. They are placed at a distance of 6m to 7.5m along the straight length and 3m to 3.6m along the curves.
- The complete route from the runway to the apron should be easily identified.
- The edge lights should not extend more than 75cm above the pavement surface.


DEPARTURE
FINAL
9
27
CROSSWIND
SEGMENTED CIRCLE
BASE
DOWNWIND
ENTRY

Landing Direction Indicator

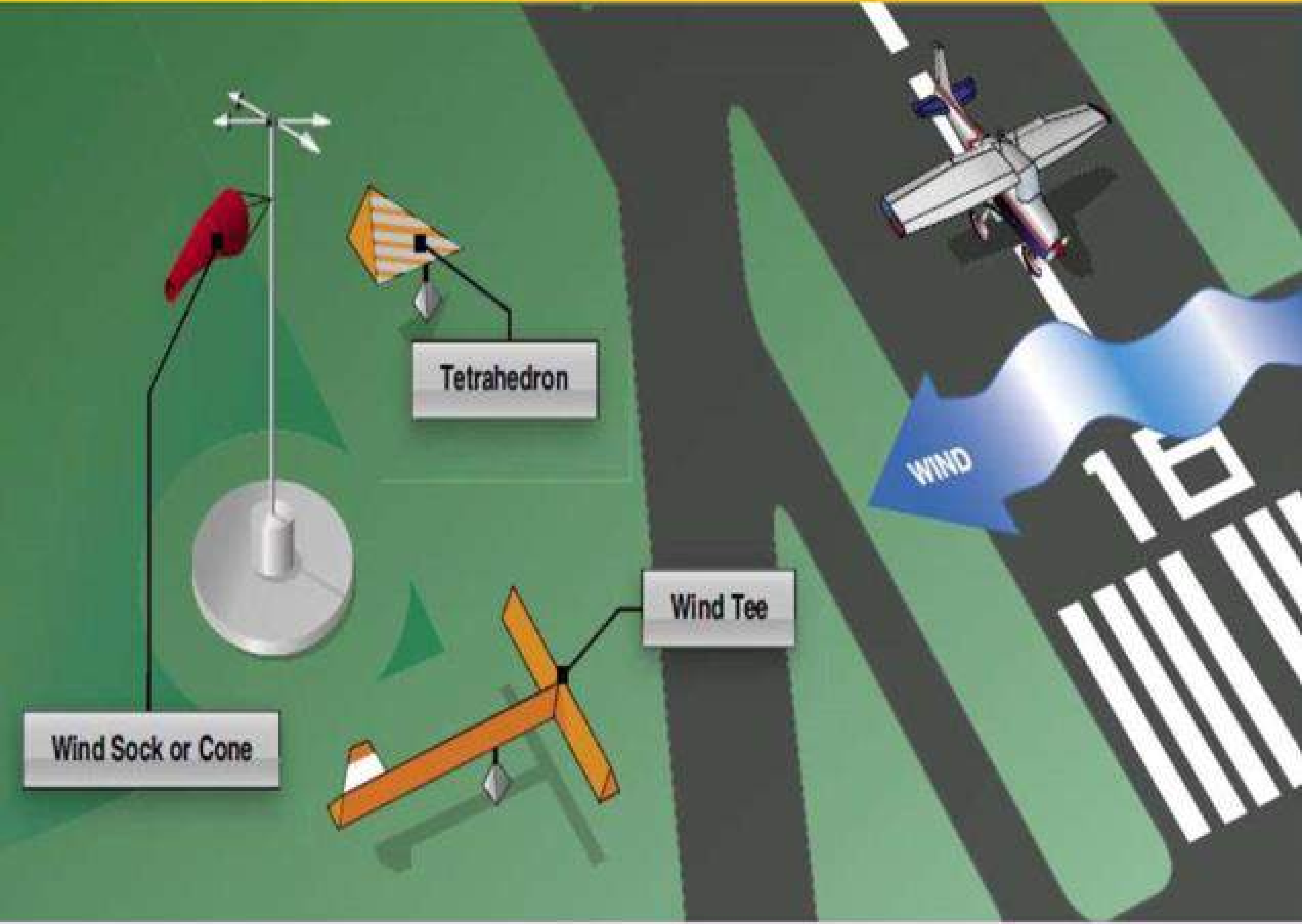
- To indicate the landing direction an arrow or a Tee is placed at the center of a segmented circle
  - Helps in identifying the runway strip and the direction from which they can land
  - Shape is arrow, or Tee or circle with cutoff lines
- It is painted in orange or white colour
- It is lighted for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

Wind Direction Indicator

- The direction from which the wind blows is indicated by a wind cone
- It is placed in a segmented circle together with the landing direction indicator
- It should be placed away from buildings so that it is not effected by eddies
- Panels forming segmented circle are gable roof shaped with a pitch of atleast 1:1

Wind direction indicator

- Panels are painted white
- Length of wind direction indicator should not be less than 3.6m and its diameter at the larger end should not be less than 90cm
- It should be visible from a height of 30m
- It is painted with bands of colours like white and black, red and white, orange and white etc.


Tetrahedron
WIND
16
Wind Tee
Wind Sock or Cone

CHAPTER 5. INSTRUMENT FLIGHT RULES

5.1 Rules applicable to all IFR flights

5.1.1 Aircraft equipment

Aircraft shall be equipped with suitable instruments and with navigation equipment appropriate to the route to be flown.

5.1.2 Minimum levels

Except when necessary for take-off or landing, or except when specifically authorized by the appropriate authority, an IFR flight shall be flown at a level which is not below the minimum flight altitude established by the State whose territory is overflown, or, where no such minimum flight altitude has been established:

a) over high terrain or in mountainous areas, at a level which is at least 600 m (2 000 ft) above the highest obstacle located within 8 km of the estimated position of the aircraft;

b) elsewhere than as specified in a), at a level which is at least 300 m (1 000 ft) above the highest obstacle located within 8 km of the estimated position of the aircraft.

Note 1.— The estimated position of the aircraft will take account of the navigational accuracy which can be achieved on the relevant route segment, having regard to the navigational facilities available on the ground and in the aircraft.

Note 2.— See also 3.1.2.

5.1.3 Change from IFR flight to VFR flight

5.1.3.1 An aircraft electing to change the conduct of its flight from compliance with the instrument flight rules to compliance with the visual flight rules shall, if a flight plan was submitted, notify the appropriate air traffic services unit specifically that the IFR flight is cancelled and communicate thereto the changes to be made to its current flight plan.

5.2 Rules applicable to IFR flights within controlled airspace

5.2.1 IFR flights shall comply with the provisions of 3.6 when operated in controlled airspace.

5.2.2 An IFR flight operating in cruising flight in controlled airspace shall be flown at a cruising level, or, if authorized to employ cruise climb techniques, between two levels or above a level, selected from:

a) the tables of cruising levels in Appendix 3; or

b) a modified table of cruising levels, when so prescribed in accordance with Appendix 3 for flight above FL 410;

except that the correlation of levels to track prescribed therein shall not apply whenever otherwise indicated in air traffic control clearances or specified by the appropriate ATS authority in Aeronautical Information Publications.

5.3 Rules applicable to IFR flights outside controlled airspace

5.3.1 Cruising levels

An IFR flight operating in level cruising flight outside of controlled airspace shall be flown at a cruising level appropriate to its track as specified in:

a) the tables of cruising levels in Appendix 3, except when otherwise specified by the appropriate ATS authority for flight at or below 900 m (3 000 ft) above mean sea level; or

b) a modified table of cruising levels, when so prescribed in accordance with Appendix 3 for flight above FL 410.

Note.— This provision does not preclude the use of cruise climb techniques by aircraft in supersonic flight.

CHAPTER 4. VISUAL FLIGHT RULES

4.1 Except when operating as a special VFR flight, VFR flights shall be conducted so that the aircraft is flown in conditions of visibility and distance from clouds equal to or greater than those specified in Table 3-1.

4.2 Except when a clearance is obtained from an air traffic control unit, VFR flights shall not take off or land at an aerodrome within a control zone, or enter the aerodrome traffic zone or traffic pattern:

a) when the ceiling is less than 450 m (1 500 ft); or

b) when the ground visibility is less than 5 km.

4.3 VFR flights between sunset and sunrise, or such other period between sunset and sunrise as may be prescribed by the appropriate ATS authority, shall be operated in accordance with the conditions prescribed by such authority.

4.4 Unless authorized by the appropriate ATS authority, VFR flights shall not be operated:

a) above FL 200;

b) at transonic and supersonic speeds.

4.5 Authorization for VFR flights to operate above FL 290 shall not be granted in areas where a vertical separation minimum of 300 m (1 000 ft) is applied above FL 290.

4.6 Except when necessary for take-off or landing, or except by permission from the appropriate authority, a VFR flight shall not be flown:

a) over the congested areas of cities, towns or settlements or over an open-air assembly of persons at a height less than 300 m (1 000 ft) above the highest obstacle within a radius of 600 m from the aircraft;

b) elsewhere than as specified in 4.6 a), at a height less than 150 m (500 ft) above the ground or water.

Note.— See also 3.1.2.

4.7 Except where otherwise indicated in air traffic control clearances or specified by the appropriate ATS authority, VFR flights in level cruising flight when operated above 900 m (3 000 ft) from the ground or water, or a higher datum as specified by the appropriate ATS authority, shall be conducted at a cruising level appropriate to the track as specified in the tables of cruising levels in Appendix 3.

4.8 VFR flights shall comply with the provisions of 3.6:

a) when operated within Classes B, C and D airspace;

b) when forming part of aerodrome traffic at controlled aerodromes; or

c) when operated as special VFR flights.

4.9 A VFR flight operating within or into areas, or along routes, designated by the appropriate ATS authority in accordance with 3.3.1.2 c) or d) shall maintain continuous air-ground voice communication watch on the appropriate communication channel of, and report its position as necessary to, the air traffic services unit providing flight information service.

Note.— See Notes following 3.6.5.1.

4.10 An aircraft operated in accordance with the visual flight rules which wishes to change to compliance with the instrument flight rules shall:

a) if a flight plan was submitted, communicate the necessary changes to be effected to its current flight plan; or

b) when so required by 3.3.1.2, submit a flight plan to the appropriate air traffic services unit and obtain a clearance prior to proceeding IFR when in controlled airspace.