THEORY & OBJECTIVE

TRANSPORTATION ENGINEERING

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HIGHWAY ENGINEERING

THEORY

1.1 HISTORY OF HIGHWAY PLANNING IN INDIA

1.1.1 Jayakar Committee

In 1927 Jayakar committee for Indian road development was appointed. The major recommendations and the resulting implementations were

- Committee found that the road development of the country has become beyond the capacity of local governments and suggested that Central government should take the proper charge considering it as a matter of national interest.
- One of the recommendations was the holding of periodic road conferences to discuss about road construction and development. This paved the way for the establishment of a semi-official technical body called Indian Road Congress (IRC) in 1934.
- The committee suggested imposition of additional taxation on motor transport which includes duty on motor spirit, vehicle taxation, license fees for vehicles plying for hire. This led to the introduction of a development fund called Central road fund in 1929. This fund was intended for road development.
- A dedicated research organization should be constituted to carry out research and development work. This resulted in the formation of Central Road Research Institute (CRRI) in 1950, New Delhi.
- They gave more stress on long term planning programme, for a period of 20 years (hence called twenty year plan) that is to formulate plans and implement those plans with in the next 20 years.

1.1.2 Nagpur Road Plan 1943 - 1961

The roads were divided into four classes

1. National highways which would pass through states and places having national importance for strategic, administrative and other purposes.
2. State highways which would be the other main roads of a state.
3. District roads which would take traffic from the main roads to the interior of the district. According to the importance, some are considered as major district roads and the remaining as other district roads.
4. Village roads which would link the villages to the road system.
5. They suggested that the length of the road should be increased so as to give a road density of 16kms/100sq.km.

1.1.3 Bombay Road Plan 1961 - 1981

The highlights of the plan were

- It was the second 20 year road plan (1961-1981).
- The total road length targeted to construct was about 10 lakhs.
- Rural roads were given specific attention. Scientific methods of construction was proposed for the rural roads. The necessary technical advice to the Panchayaths should be given by State PWD's.
- They suggested that the length of the road should be increased so as to give a road density of 32kms/100sq.km.
- The construction of 1600 km of expressways was also then included in the plan.

1.1.4 Lucknow Road Plan 1981 - 2001

Some of the salient features of this plan are as given below

- This was the third 20 year road plan (1981-2001). It is also called Lucknow road plan.
- It aimed at constructing a road length of 12 lakh kilometres by the year 2001 resulting in a road density of 82kms/100 sq.km.
- The plan has set the target length of NH to be completed by the end of seventh, eighth and ninth year plan periods.
- It aims at improving the transportation facilities in villages, towns etc. such that no part of country is farther than 50 km from NH.
- One of the goals contained in the plan was that expressways should be constructed on major traffic corridors to provide speedy travel.
- Energy conservation, environmental quality of roads and road safety measures were also given due importance in this plan.

1.2 CROSS SECTIONAL ELEMENTS OF PAVEMENT

The features of the cross-section of the pavement influences the life of the pavement as well as the riding comfort and safety. Camber, kerbs and geometry of various cross-sectional elements are important aspects to be considered in this regard.

1.2.1 Pavement Unevenness

The longitudinal profile of the road pavement has to be 'even' in order to provide good riding comfort to fast moving vehicles and to minimise the vehicle operation cost. Presence of undulations on the pavement surface is called 'pavement unevenness'.

The unevenness of pavement surface is commonly measured by using a simple equipment called 'Bump Integrator' (BI), in terms of 'unevenness index', which is the cumulative measure of vertical undulations of the pavement surface recorded per unit length of the road.

1.2.2 Light Reflecting Characteristics

Night visibility depends upon the colour and light reflecting characteristics of the pavement surface. The glare caused by the reflection of head lights is considerably high on wet pavement surface than on the dry pavement. Light coloured or white pavement surface give good visibility at night particularly during rains; however white or light colour of pavement surface may produces glare and eye strain during bright sunlight. Black top pavement surface on the order hand provides very poor visibility at nights, especially when the surface is wet.

1.2.3 Friction

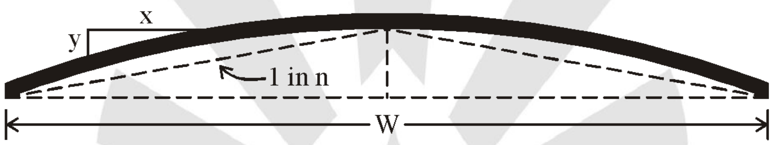
Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed. Further, it also affects the acceleration and deceleration ability of vehicles. Lack of adequate friction can cause skidding or slipping of vehicles.

- Skidding happens when the path traveled along the road surface is more than the circumferential movement of the wheels due to friction.
- Slip occurs when the wheel revolves more than the corresponding longitudinal movement along the road.
- Coefficient of longitudinal friction = 0.35 to 0.4, Coefficient of lateral friction = 0.15

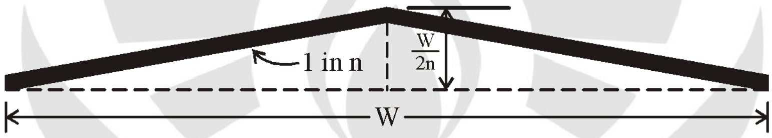
1.2.4 Camber

Camber or cant is the cross slope provided to raise middle of the road surface in the transverse direction to drain of rain water from road surface. The objectives of providing camber are

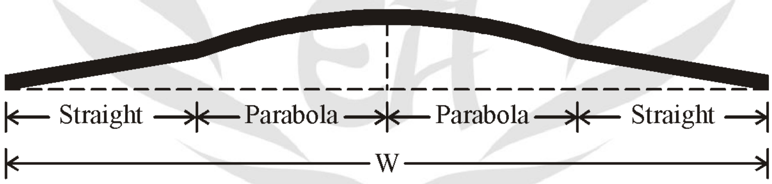
- Surface protection especially for gravel and bituminous roads.
- Sub-grade protection by proper drainage.
- Quick drying of pavement which in turn increases safety.



(a) Parabolic camber $y = \frac{2x^2}{nW}$



(b) Straight line camber $y = \frac{W}{2n}$



(c) Combination of straight and parabolic camber

Fig. : Different types of camber

Table : IRC values for camber

S. No.	Surface type	Heavy rain	Light rain
1.	Concrete/Bituminous	2 %	1.7 %
2.	Thin bituminous surface	2.5 %	2 %
3.	Gravel/WBM	3 %	2.5 %
4.	Earthen	4 %	3 %

1.2.5 Width of Carriage Way

Width of the carriage way or the width of the pavement depends on the width of the traffic lane and number of lanes. Width of a traffic lane depends on the width of the vehicle and the clearance. Side clearance improves operating speed and safety. The maximum permissible width of a vehicle is 2.44 m.

PRACTICE SHEET

OBJECTIVE QUESTIONS

1. Pick up the correct statement for the following
   (a) Tar concrete pavements are suitable if fuel spillage occurs
   (b) Rubberised tar concrete hot blast as well as spillage
   (c) Epoxy asphalt concrete resists the jet fuels and provides more elastic pavements
   (d) All the above
2. The depression and undulations in the pavement, are caused due to
   (a) Improper compaction of subgrade
   (b) impact of heavy wheel loads
   (c) Punching effect
   (d) All the above
3. California Bearing Ratio (CBR)
   (a) Is a measure of soil strength
   (b) Is a procedure for designing flexible pavements
   (c) Is a method of soil identification
   (d) is a measure to indicate the relative strengths of paving materials
4. Which one of the following methods is used in the design of rigid pavements?
   (a) CBR method
   (b) group index method
   (c) Westergaards method
   (d) Mc Leods method
5. Radius of relative stiffness of cement concrete pavement does not depend upon which one of the following?
   (a) Modulus of subgrade reaction
   (b) Wheel load
   (c) Modulus of elasticity of cement concrete
   (d) Poissons ratio of concrete
6. Bituminous materials are used in highway construction primarily because of their
   (a) Cementing and water proofing properties
   (b) Load bearing capacity
   (c) High specific gravity
   (d) Black colour which facilitates road markings
7. An Enoscope is used for measuring
   (a) Running speed (b) Time mean speed
   (c) Spot speed (d) Overall speed
8. Which set of traffic studies is needed for functional design as well as for highway capacity design?
   (a) Origin and destination studies
   (b) Parking and accident studies
   (c) Speed and volume studies
   (d) Axle load studies
9. A vehicle travelling on dry, level pavement at 80 kmph, and the breaks applied. the vehicle travelled 80 m before stopping. The coefficient of friction that will be developed
   (a) 0.325 (b) 0.315
   (c) 0.345 (d) 0.355
10. The absolute minimum radius for a horizontal curve designed for speed of 100 kmph given the permissible values of super elevation 0.08 and coefficient of friction 0.12 will be
    (a) 394 m (b) 295 m
    (c) 364 m (d) 252 m
11. Which of the following are the criteria associated with the design of sag vertical curve?
    1. Provision of minimum stopping distance during day time
    2. Adequate drainage
    3. Comfortable operation
    4. Pleasant appearance

    Select the correct answer using the codes given below :
    (a) 1, 2 and 4 (b) 2 and 3
    (c) 2, 3 and 4 (d) 1 and 3
12. Assuming the safe stopping sight distance to be 80 m on a flat highway section and with a set back distance of 10 m. What would be the radius of the negotiable horizontal curve?
    (a) 800 m (b) 160 m
    (c) 80 m (d) 70 m

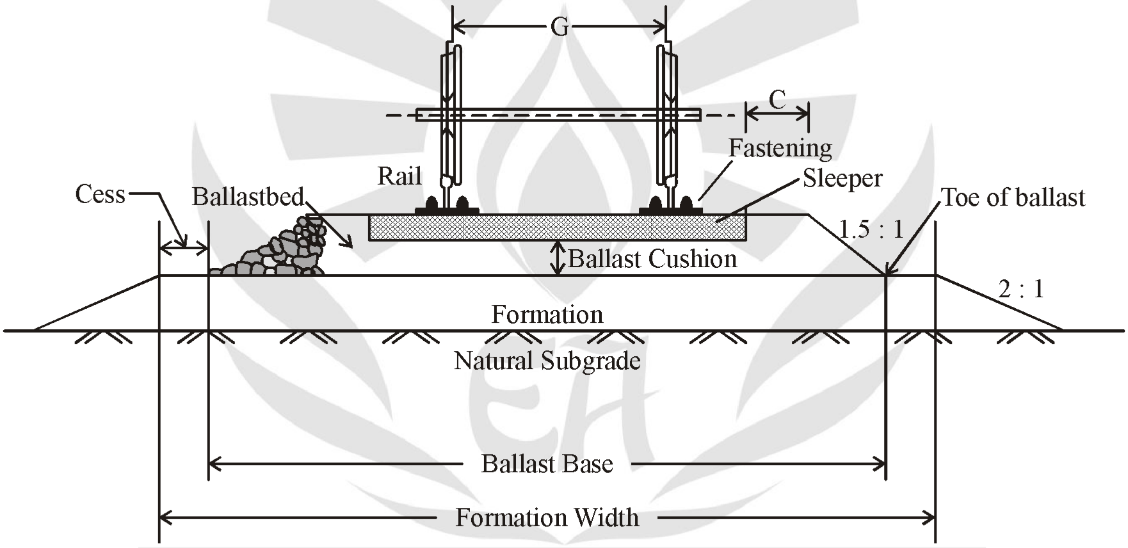
2

RAILWAY ENGINEERING

THEORY

Railway track is called permanent way to distinguish it from the temporary tracks laid for conveyance of earth and materials on construction works. Permanent way is the combination of rails, fitted on sleepers with the help of fixtures and fastenings and resting on ballast and subgrade is called the railway track or permanent way.

2.1 TRACK STRUCTURE

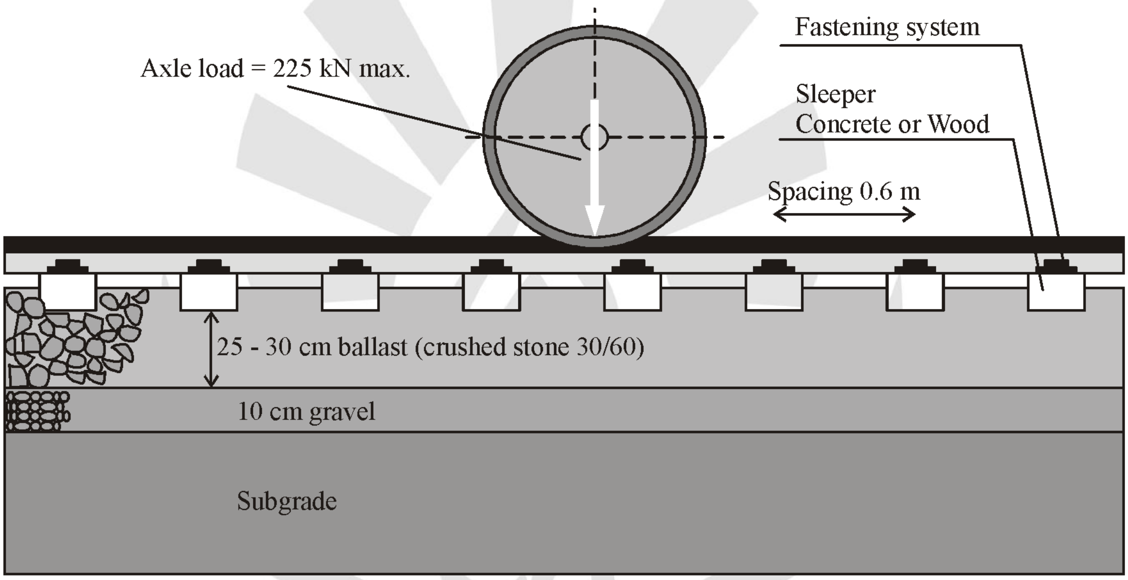


2.2 TRACK COMPONENTS

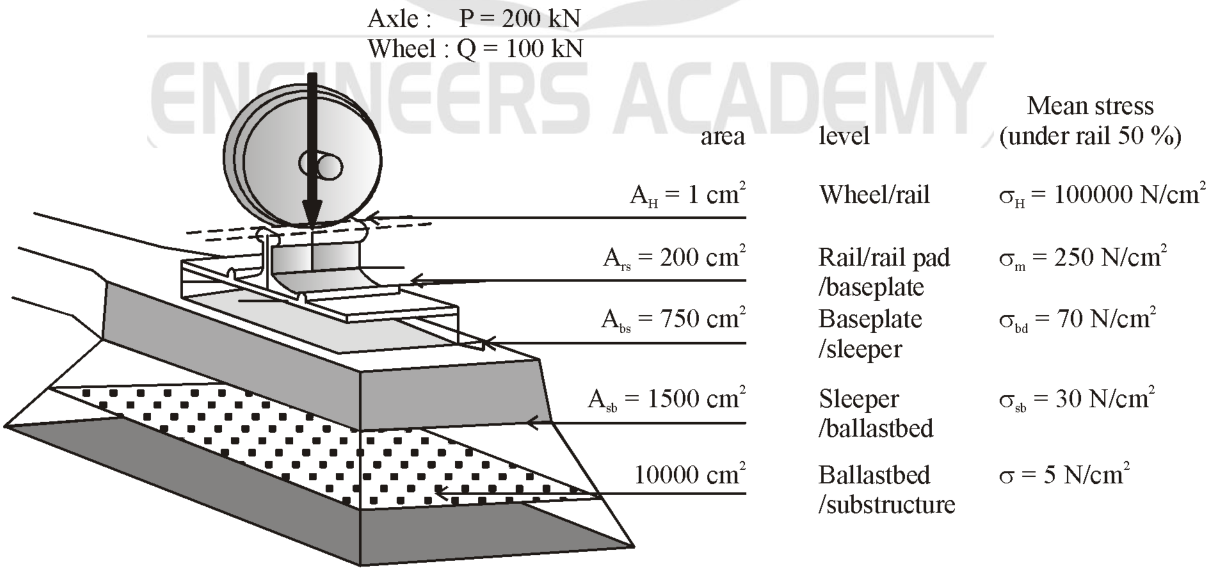
- **Gauge :** The distance between the running or gauge faces of the two rails measured 14 mm below the top surface
- **Rails :** Rails act as girders to transmit the wheel load to the sleepers. Rails are joined in series by welding a few of them (5 of them) and the welded lengths are joined by fish plates and bolts. Rails are fixed to sleepers by different types of fixtures and fastenings.
- **Sleepers :** Sleepers hold the rails in proper position with respect to their proper tilt, gauge and level and transmit the load from rails to the ballast. These sleepers are suitably spaced, packed and boxed with ballast. The typical length of a BG sleeper is 2.7 m.
- **Ballast :** Ballast is a high quality crushed stone with desired specifications placed directly below the sleeper. Ballast distributes the load over the formation and holds the sleepers in position and also functions as drainage layer.

- **Formation :** Formation is the compacted and prepared subgrade which is the part of embankment or cutting. Natural subgrade is the soil in the natural ground on which the track rests.
- **Ballast cushion :** The depth of ballast below the bottom of the sleeper, normally measured under rail seat is termed as ballast cushion.
- **Ballast shoulder :** Ballast provided beyond the sleeper edge is termed as ballast shoulder (shown as C in Fig., typically 0.35 m in a BG track).
- **Ballast Base :** It is the bottom width of ballast-bed (typically 4.4 m in a BG track).
- **Formation width :** It is the top width of embankment or bottom width of cutting (Typically 6.1 m in a BG track).
- **Cess width :** Width of formation beyond the toe of ballast is termed as cess width.

2.3 CONVENTIONAL TRACK STRUCTURE

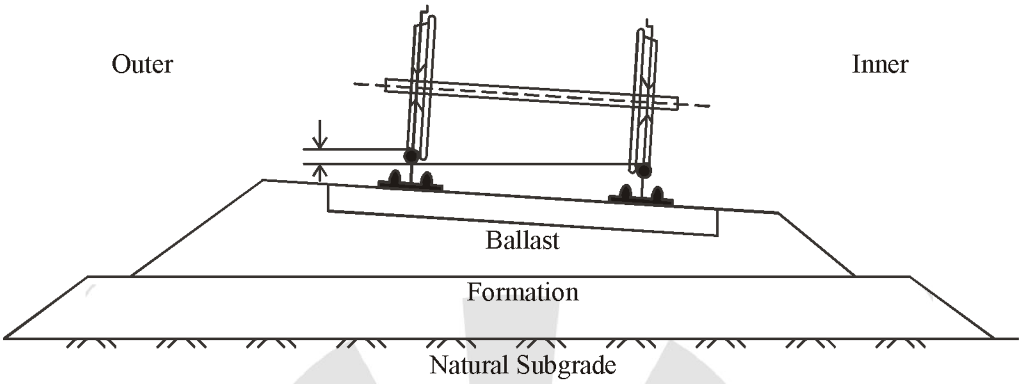


2.4 LOAD-BEARING FUNCTION OF THE TRACK



2.5 TRACK ON A CURVE

Superelevation is maintained by varying the ballast cushion and the formation is kept level. Minimum cushion is maintained at the inner rail, while the outer rail gets more ballast cushion.



2.6 VARIOUS GAUGES ON WORLD RAILWAYS

The most widely used gauge in the world is the standard gauge.

Type of Gauge	Gauge Distance	Percent of Total Length	Countries
Standard Gauge	1.435	62	Europe, USA, China, Australia, Persia, etc.
Broad Gauge (BG)	1.676	6	India, Pakistan, Sri Lanka, Argentina, Brazil
Metre Gauge (MG)	1.000	9	India, France, Switzerland, Argentina
Other Gauges	Different Gauges	23	Various Countries

2.7 LENGTH OF INDIAN RAILWAY TRACK

Type of Track	Length*, km
Broad Gauge (BG)	46806
Metre Gauge (MG)	13290
Narrow Gauge (NG)	3124
total track route km	63220
Total running track km	83859
Total track km	108486

- **Route kilometer :** This is the route length of railway between origins and destinations.
- **Running track kilometer :** This is the length of running track on a route. On a route with double track, the running track kilometer is about twice the route kilometer.
- Total track kilometer is the physical length of track available. This length is arrived at after giving due weightage for the length of track on track junctions, sidings, etc., and adding it to the running track kilometer.

2.7.1 Advantage of Larger Gauge

- Larger the gauge, greater is the traffic capacity, speed and safety.
- However, larger gauge requires flatter gradients and curves.
- Though the cost of construction increases with gauge, in many cases the increase in cost is marginal.

2.8 SELECTION OF GAUGE

2.8.1 Cost of Construction

- There is proportional increase in the cost of acquisition of land, earthwork, rails, sleepers, ballast, and other track items with gauge
- The cost of bridges, tunnels and culverts increases only marginally with gauge
- The cost of station buildings, platforms, signals etc., is same more or less for all gauges
- The cost of rolling stock also increases marginally for larger gauges
  - ✧ Volume and nature of traffic
  - ✧ Speed of movement (wheel diameter = $0.75 \times$ Gauge)
  - ✧ Development of areas
  - ✧ Physical features of the country

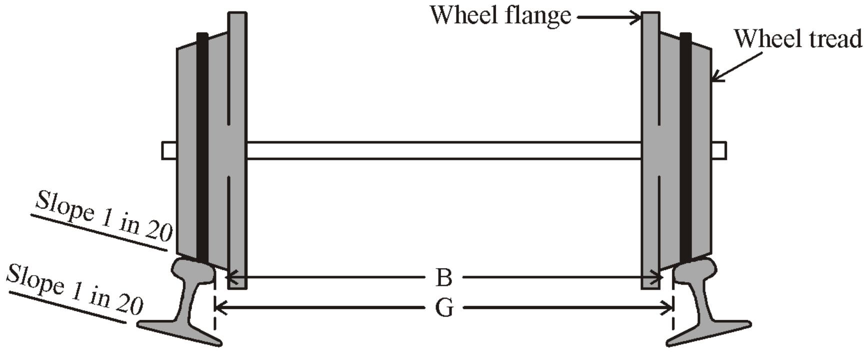
2.8.2 Uniformity of Gauges

- Gauge to be used in a particular country should be uniform throughout as far as possible.
- Whenever there is change of gauge, there has to be transshipment of passengers and goods.
- This causes duplication of equipment, surplus wagons and locomotives.
- Uniformity of gauge is ideal for any country.
- In India, the uniformity of gauges is being achieved by a gradual conversion of MG to BG.
- In view of its heavy financial implications the progress has been slow.

2.8.3 Progress of Gauge Conversion in India

Period	Length of Conversion (km)
1947 – 1993	2500 (approximate)
1993 – 1997	6897
1997 – 2001	1892
2001 – 2004	1895

2.9 CONING OF WHEELS



3

AIRPORT ENGINEERING

THEORY

3.1 AIRCRAFT CHARACTERISTICS

3.1.1 Size of Aircraft

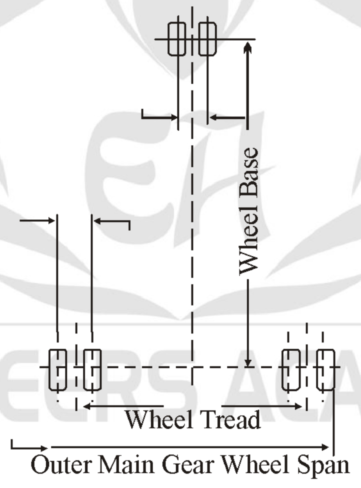
Wing span : Distance between two wing tips. Determines separation clearance between two parallel taxiways, size of gates, turning radius, etc.

Fuselage length : The overall length of aircraft from tip of nose to the tail. It determines size of gate, turning radius, etc.

Height : Determines the vertical clearances required in hangar and other service areas.

Wheel base : Centre to centre distance between nose gear and landing gear. Determines the minimum turning radius.

Wheel tread / Outer main gear wheel span : The centre to centre distance between the two landing gears is wheel tread. The outer to outer distance between the two landing gears is outer main gear wheel span.



These dimensions effect the minimum turning radius, width of taxiway, etc.

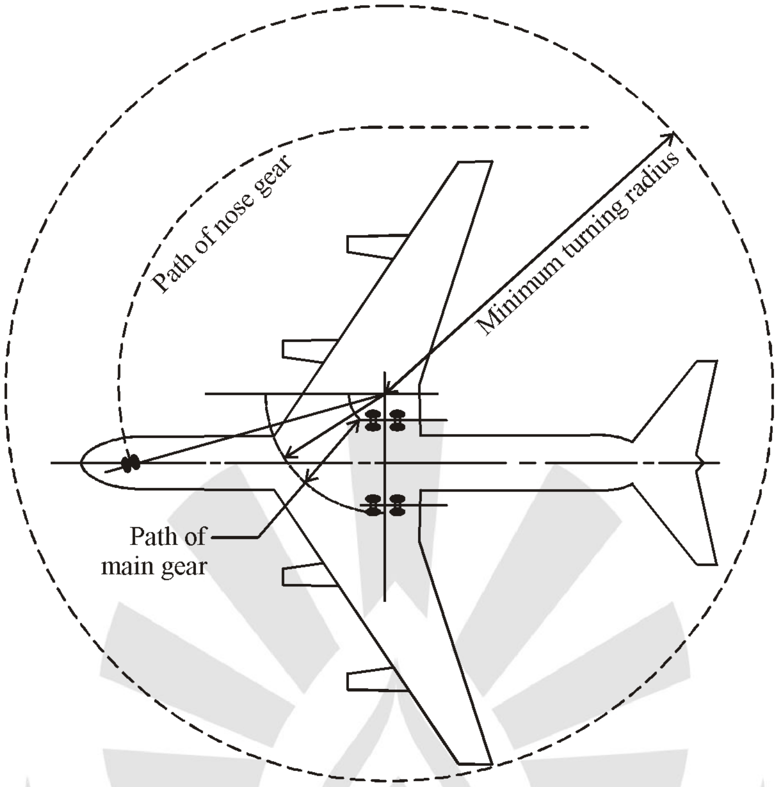
3.1.2 Minimum Turning Radius

This dimension is important for establishing the geometry of movement of the aircraft.

The exact position of the aircraft adjacent to the terminal building and the path of the aircraft at other locations is determined based on the turning radius.

Turning radius is a function of nose gear turning angle (caster angle). The maximum turning angle varies between 60° – 80°.

However, while working out minimum turning radii, moderate caster angle (50) is used to minimize the wear and tear of nose gear minimum circling radius.



Plan

This is the minimum radius with which aircraft can take turn in space. It depends on type of aircraft, air traffic volume, weather condition, etc. Also it determines the spacing between two airports.

Typical values for minimum circling radii

- Small general aviation aircrafts operating under visual flight Rules. **1.6 km**
- Bigger aircrafts operating under Visual Flight Rules **3.2 km**
- Piston Engine aircrafts operating under Instrument Flight Rules **13 km**
- Jet Engine aircrafts operating under Instrument Flight Rules **80 km**

3.1.3 Speed of Aircraft

Speed of aircraft is measured either with respect to ground (termed as cruising speed or ground speed) or relative to wind (termed as air speed). Speed of aircraft is reported in Nautical Miles per hour (1 nautical mile = 1.85 km). Approach speed, touchdown speed, exit speed and allowable deceleration values determine the location and design of exit taxiways.

3.1.4 Aircraft Weight

Operating Empty Weight (OEW) : Weight of aircraft excluding payload and fuel, but including crew and necessary gear required for flight.

Zero Fuel Weight (ZFW) : The weight above which all additional weight must be in terms of fuel, so that, when the aircraft is in flight, the bending moments at the junction of wing and fuselage do not become excessive.

Payload : This is the total revenue producing load : passengers + baggage + mail + cargo.

Maximum structural payload : The maximum payload the aircraft is certified to carry.

Theoretically, Maximum Structural Payload = ZFW – OEW

Actual payload often is less than this as much of space is occupied by seats, etc.

Maximum ramp weight : This is the maximum total weight of the aircraft authorized for ground maneuver.

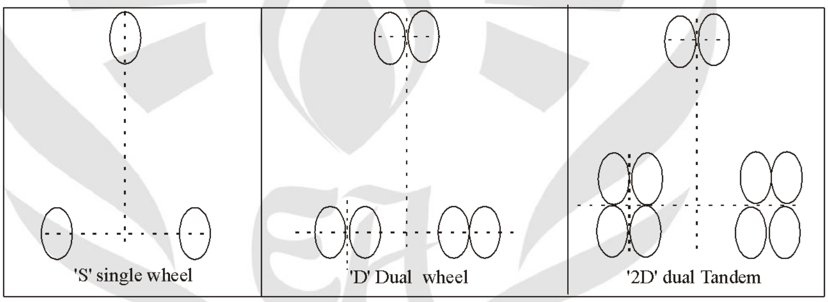
Maximum structural takeoff weight : The maximum weight of the aircraft authorized at brake release for takeoff. It excludes taxi and run-up fuel and includes, OEW, payload and trip and reserve fuel. Thus, the difference between ramp weight and takeoff weight is nominal.

Maximum structural landing weight : This is the weight for which the landing gear is designed. The total weight of the aircraft cannot exceed this while landing. Maximum structural landing weight is less than the maximum structural takeoff weight as aircraft loses weight enroute by burning fuel. In case of abortive takeoff, the fuel is jettisoned so as not to exceed the maximum structural landing weight.

3.1.5 Gear Configuration

- Aircrafts are supported by a nose gear and two main landing gears located on the wing area on each side.
- The distribution of the load between the main gears and the landing gear depends on the type of aircraft and the location of the centre of gravity of the aircraft
- However, for pavement design it is normally assumed that 95% of the weight is supported on the two landing gears.
- Maximum ramp weight is used while working out the distribution of load for pavement design purposes.

GEAR CONFIGURATION



3.1.6 Range of Aircraft

Range of an aircraft is the maximum distance it can fly satisfying the norms relating to reserve fuel and the maximum weight characteristics.

When the aircraft is loaded to its maximum structural payload (P_A), the fuel tanks can not be completely filled to satisfy the requirement of maximum structural takeoff weight limiting the range (say to R_A).

In order to maximize the range (say to R_B), the payload has to be reduced (say to P_B) giving way for additional fuel filling the fuel tanks completely.

When the aircraft is not on a passenger flight, the requirements of reserve fuel will not apply. The range worked out by considering maximum trip fuel and reserve fuel under zero payload is termed as ferry range (R_C).

The payload vs range curves are given by the manufacturer. These curves are useful in the planning of airport.

Using these curves the exact weight characteristics of the aircrafts can be obtained by knowing their scheduled operations.

3.2 BASIC RUNWAY LENGTH

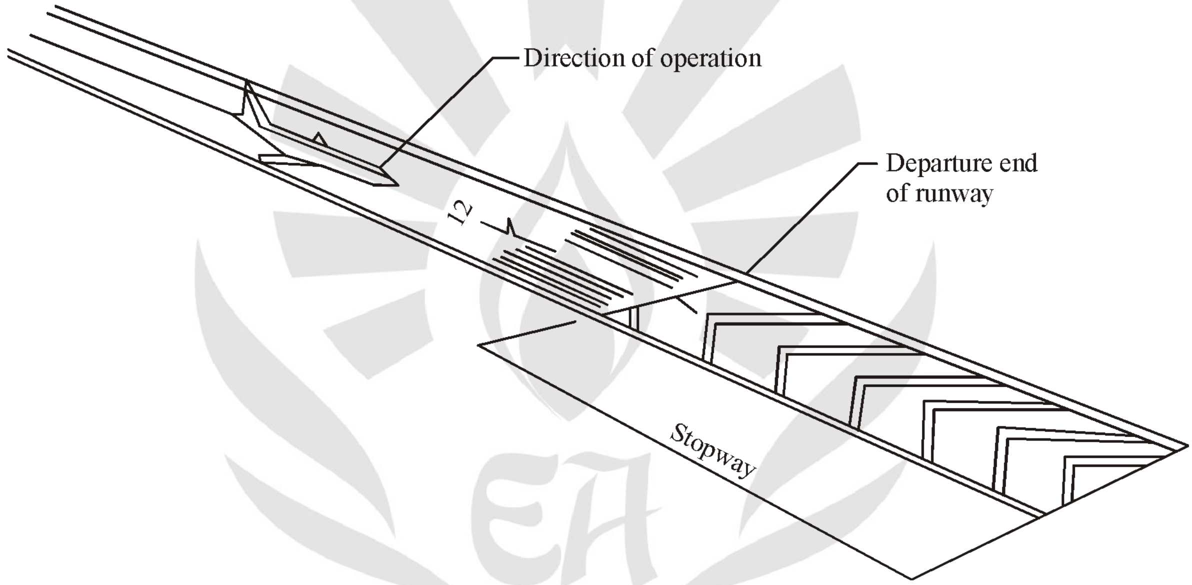
Basic runway length is the length of runway required based on the imposed performance requirements of the critical aircraft under standard conditions. Basic runway length has to be determined for the following three general cases :

- Normal landing case
- Normal takeoff case
- Engine stopping case

3.2.1 Runway Components

The three basic components of runway are :

1. **Full strength pavement (FS) :** Full strength pavement should support the full weight of the aircraft.
2. **Stopway (SW) :** Stop way is a paved surface that allows an aircraft overrun to take place without harming the vehicle structurally (cannot be used for takeoff).



3. **Clearway (CW) :** Clearway is a prepared area beyond FS, clear of obstacles (max slope is 1.25%), allowing the aircraft to climb safely to clear an imaginary 11m (35′) obstacle.