1 Rail, Railway and Rail Joints

Rail: These are steel girders for the purpose of carrying axle load made up of **high carbon steel** which convert **moving wheel loads of train into point load**,which then acts on sleepers.

Requirement of Rails:

(*i*) Rails are tested by falling weight text.

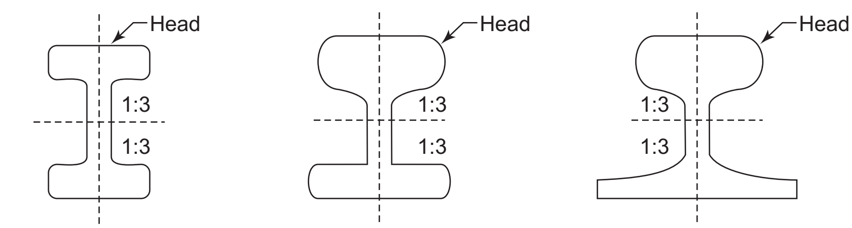
(*ii*) Rails are manufactured by open heart or duplex process.

(*iii*) Maximum wear of head allowed is 10mm

(*iv*) Minimum tensile strength needed 72 kg/m^2.

Types of Rail

- Double Headed rail
- Bull Headed rail
- Flat footed rail



Double headed Rail   Bull headed Rail   Flat Torted Rail

Note: 52 kg rail (i.e. 52kg/m F.F) is suitable upto 130 kmph and 60 kg rail is suitable upto speed of 160 kmph.

Length of Rail: Rails of larger length are always preferred as they will have less no. of joints. Rail length of 12.8m for BG tracks and rail length of 11.8 gm for MG tracks are used in Indian railways.

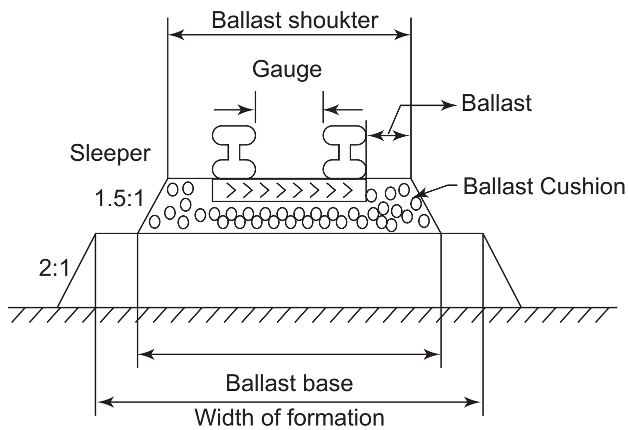
Note : $\boxed{\dfrac{\text{wt. of Rail}}{\text{wt. of locomotive}} \approx \dfrac{1}{510}}$

when wear of head exceeds 5% of total weight, the rail is to be replaced.

Permanent way OR Railway Track

⇒ Sometimes temporary tracks are laid down for material transportation. Hence, word permanent way is coined for railway track.

⇒ It is **Semi-elastic in** nature due to packing of ballast cushion.



Defects of Rail

- Corrugated Rails
  Minute depression on the Surface of rails
- Kinks in rail
  Ends of adjoining rails move slightly out of position
- Hogged rail
  At ends of rails, down due to impact heads get bend action of wheel
- Buckling of rail
  Due to change intemperature, when there is insufficient gap b/w two end joints.

Ganges in Railway Track: It's the clear distance between inner faces of two track rails.

Broad Gauge = 1.676m

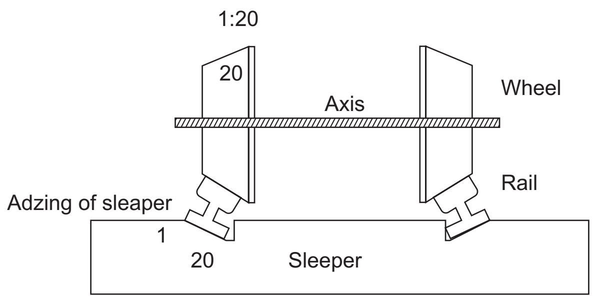
Narrow Gauge = 0.762m

Meter Gauge = 1.0m

Standard gauge = 1.435m (Delhi metro)

Coning of wheels: Wheels of the train are made at a slope of 1:20. Thus is known as coning of wheels.

Adzing of sleepers: For effective use of coning of wheels, the rails are also laid at the slope of 1 in 20 on the sleepers.



Rail Joints: Are needed to hold together the adjoining ends of the rail. They are the weakest part of the track.

Types of Rail joints

- Supported → Rail ends rests on a single sleeper
- Suspended → Rail ends are projected beyond sleepers
- Bridge → projected rail ends are connected by a flat or plate.
- Compromise → Two different rail sections are joined by fish plates.
- expansion → Gap is provided for thermal expansion
- Welded → Most perfectand strongesttype of Joints.

Welded Rails: Rails are welded to provide sufficient restrain at the ends of rail and better degree of fixity of rail to the sleeper so that the stresses produced are resisted by sleeper fasteners.

- Short welded Rail (SWR) → 3 rail lengths are welded (by standards of Indian Railways)
- Long welded Rail (LWR) → Minimum length of 200m(BG) or 300m (MG) is welded at both ends
- Continuous welded Rail (CWR) → Rail longer than 1 km and extending from 1 station to another

Length of welded Rail:

$$\boxed{L = (n-1)S}$$

$$\boxed{n = \frac{\alpha T E_s A_s}{R}}$$

S = sleeper spacing

n = No. of sleepers required

α = coefficient of thermal expansion

T = rise in temperature

E_S = modulus of elasticity

A_S = cross. sectional area of rail

R = resisting force/sleeper

Breathing length: minimum length of rail required to be welded at the end of track, so the portion of rail between welded rail does not undergo any thermal expansion or contraction.

2 Sleepers and Track Fasteners

Sleepers are the members which support the rail and are laid transverse to it. They act as elastic medium for providing longitudinal and lateral stability to the track.

Classification of sleepers

- Wooden sleepers
- Metal sleepers
  - Cast iron
    - Pot or Bowl
    - plate
    - Box
    - CST 9
  - Steel sleepers
- Concrete sleepers
  - Reinforced concrete
  - Prestressed concrete

⇒ Wooden sleepers are best sleepers but they have maximum life of 12-15 years.

⇒ C.I sleepers are used more than steel sleepers as they are less prone to corrosion.

⇒ C.I sleepers can be used with every type of ballast but are not suitable for track circuiting.

⇒ CST 9 sleeper has inverted triangular pot on either side of the rail section and a plate with the projecting rib and a box on top of the plate.

⇒ Steel sleepers are light in weight, require less no. of fasteners but get easily rusted.

⇒ Concrete sleepers have high track modulus, hence used for developing high speed tracks.

Note: Serviceable portion of the spiked killed wooden sleepers is cut and used with tie bars in station yards is known as check sleepers.

Composite Sleeper Index (C.S.I): used to measure the mechanical strength of timber.

$$CSI = \frac{S + 10\,H}{20}$$

S = strength Index H = Hardness Index

Both Index are measured at 12% moisture content

Track fasteners:

(i) Fish plates: used to join two rail joints.
(ii) Spiker: hold's rail on wooden sleepers.
(iii) Bolts: used where sleepers rest on steel girders.
(iv) Chair: support bull headed rails on sleepers.
(v) Keys : fix rails to chairs on metal sleepers
(vi) Bearing plates: used below F.F rails to distribute load over wooden sleeper.

Sleeper density: No. of sleepers per rail length. Its M + x

Where M = rail length (13 for BG)
x = varies b/w 3 to 7

for BG sleeper density is M+5 i.e. 18 sleepers/rail.

Squaring of Sleeper: Adjusting ballast under the sleepers to space them parallel to each other.

3 Ballast, Sub-grade and Track Alignment

Ballast: It's high Quality crushed stone with desired specifications placed immediately beneath the sleepers.

Ballast Cushion: Depth of ballast below the bottom of the sleeper, normally measured under the rail seat. On the curved track super-elevation is maintained by ballast cushion.

Types of ballast

(i) Broken stone: Best material as ballast, has maximum stability.

(ii) Gravel or River pebble: Smooth and round so poor packing and interlocking.

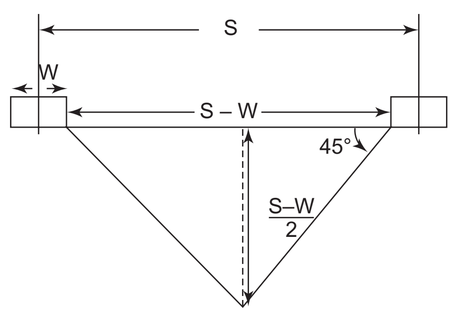
(iii) Sand: Good drainage, provides silent track, blown off due to vibrations

(iv) Asher or girders: Excellent drainage property, Excellent ballast material for station yards.

Minimum depth of Ballast layer = D_{min}

$$D_{min} = \frac{S - W}{2}$$

Depth of ballast-Section



Packing: Process of ramming the ballast underneath the sleeper.

Boxing: Loosely filled ballast above the packed layer.

Subgrade: Naturally occurring soil prepared to receive the ballast.

The ideal material for subgrade is soil containing gravel, sand, clay and silt in equal proportion with moisture content just above the plastic limit.

Subgrades can be improved by

(i) adding mixture of sand, silt and clay

(ii) providing blanket of non-cohesive soil over poor cohesive soil.

(iii) injecting mixture of cement and sand under pressure.

(iv) providing concrete mats to stabilise poor subgrade.

Survey works for alignment of track.

(i) Traffic survey

(ii) Reconnaissance survey

(iii) Preliminary survey

(iv) Detailed or location survey

Track Stresses & Creeps of Rail

4

Track Modulus (μ): Load per unit length of the rail reoccurred to produce unit deformation or depression in the track.

Note: Elasto – plastic theory is used to define tack modulus

Stresses on the rail: Torsional stresses are developed due to eccentric vertical loads while max shear stress below the contact surface of rail and diesel locomotive is 36.25 kg /mm^2

Hammer blow effect: Alternate lifting and sudden pressing is called hammer blow

$$\text{Hammer blow} = 0.14 \times \frac{M}{g} \times (2\pi n)^2 \sin\theta$$

Where, M = Net over weight in kg
r = Crank pin diameter in m
n = Number of revolutions of wheel per sec
θ = Crank angle

Steam Effect: The vertical component of pressure of steam acting on piston is given in F.P.S units as

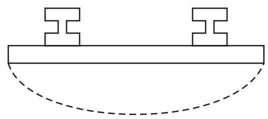
$$P_v = \left(\frac{\pi}{4} d^2\right) P \left(\frac{r \sin\theta \pm h}{L}\right)$$

Where, L = Length of connecting rod in inches
d = diameter of piston in inches
H = height of cross head above the centre line of driving wheel in inches
= Crank angle.

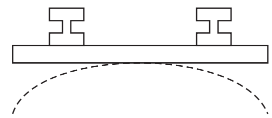
Inertia of reciprocating forces

$$F_v = \frac{m}{g} r(2\pi n)^2 \left(\cos\theta + \frac{r}{L}\cos 2\theta\right)\left(\frac{r\sin\theta \pm h}{L}\right)$$

Stresses on sleeper



Deflection under newly Constructed sleepers



Depressions at ends due to repeated action of loads.

Method of calculating longitudinal bending stress in rail.

(i) $X_i = 42.33\sqrt{\dfrac{I}{\mu}}$

x_i = distance from the load to the point of contraflexure of the rail in cm

I = vertical moment of inertia of rail section in cm4

μ = Track modulus in kg/cm^2

(ii) $\sigma_{comp} = \dfrac{m_0}{Z_{comp}}$ tonnes/cm^2 $\sigma_{tension} = \dfrac{m_0}{Z_{tension}}$ tonnes/cm^2

m_0 = B.M in tonne cm immediately under an isolated load p tonne on one rail.

$Z_{comp}/Z_{tension}$ = section modulus of rail in compression/tension

$\sigma_{comp}/\sigma_{tension}$ = consequent compressive/tensile stress in the rail head/foot under the load p in tonne per square cm

(*iii*) $d = \dfrac{9.25p}{4\sqrt{I\mu^3}}$ d = deflection of track in cm

P = load on one rail in tonnes.

Creep of the rail: It's the longitudinal movement of rail with respect to sleepers in a tack.

Theories of creep

- Wave Action theory ⇒ Vertical reverse curve due to longitudinal movement in the traffic direction.
- Precursion theory ⇒ due to horizontal component of the resultant impact force at the rail end
- Drag theory ⇒ Drag of driving wheel of locomotive have opposite effect with respect to direction of creep.

Prevention of creep:

(i) Pulling back rails to original position

(ii) Using steel sleepers

(iii) By providing sufficient crib ballast

Factors governing creep of the rail:

(i) Alignment of track: observed greater on curves

(ii) Grade oftrack: more creep in downward steep gradients.

(iii) Type ofrails: old rails have more creep

(iv) More creep in the direction of heaviest traffic.

5 Geometric Design of the Track

Gradient: Any rise or fall in track level is called gradient

- **Ruling Gradient**
  ⇒ (a) In plain regions 1 in 150 to 1 in 200
  (b) In hilly regions 1 in 100 to 1 in 150
- **Momentum Gradient**
  ⇒ It's sleeper than ruling gradient and comes only after a falling gradient
- **Helper or pusher**
  ⇒ Gradient A Hel per or pusher engine is used.
- **Gradients at station yard**
  ⇒ 1 in 400 to 1 in 1000
  ⇒ Provided to drain off the water.

Grade compensation: Due to curvature on the grade, the gradients on the curves are to be reduced to reduce the resistance in motion of train.

	% per degree of curve
BG	0.04
MG	0.03
NG	0.02

Safe speed of train as per Martin's Formula

- For low speed (<100 kmph) (>100 kmph)
  - Transitioned curve
    - on BG & MG: $V_{max} = 4.35\sqrt{R-6.7}$
    - on NG: $V_{max} = 3.6\sqrt{R-6.1}$
  - Non-trasitioned curve 80% of speed on transitioned curve.
- For High speed
  - $V_{max} = 4.58\sqrt{R}$ BG

Degree of Curve:

For 30m chain	$\frac{1720}{R}$

For 20m chain	$\frac{1150}{R}$

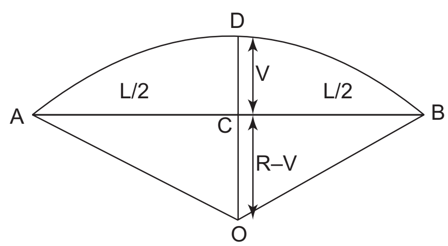
As per Indian Railways,

	Maximum degree of curve	Minimum radius
BG	10°	175m
MG	100°	109m
NG	50°	44m

Versine of curve: used to check the accuracy of the curve

$$\text{Versine} = V = \frac{L^2}{8R} \quad V = \text{cm}$$

L, R = m

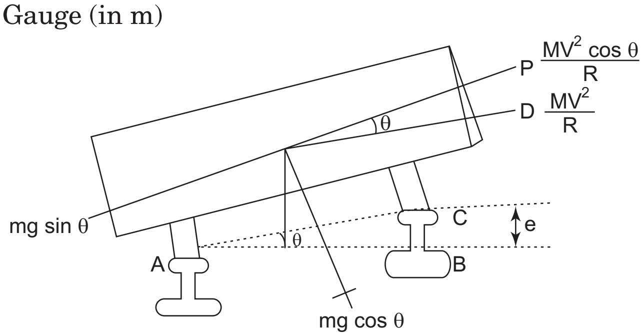


Super elevation or cant

$$\tan\theta = \frac{e}{G} = \frac{v^2}{gR}$$

$$\boxed{e = \frac{Gv^2}{127R}}$$ V in kmph
R in m

G → Gauge (in m)



Equilibrium Speed

Maximum limit of super elevation

Track	Speed<120kmph	>120 kmph
BG	16.5 cm	18.5 cm
MG	10 cm	×
NG	7.6 cm	×

Equilibrium speed

When sanction speed > 50 kmph

$$V_{equ} = \min \begin{cases} \frac{3}{4} V_{max} \\ \text{safe speed by martin} \end{cases}$$

When sanction speed < 50 kmph

$$V_{equ} = \min \begin{cases} 50 \text{ kmph} \\ \text{safe speed by martin} \end{cases}$$

$$\boxed{\text{Weighted average speed} = \frac{\Sigma N_i V_i}{\Sigma N_i}}$$

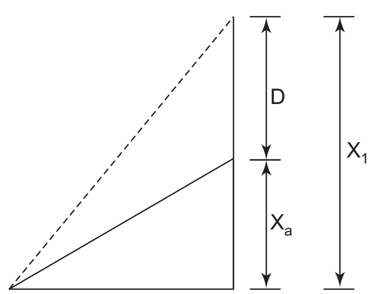
N_i = Number of train's having speed V_i

Can't Deficiency: For trains running with higher speed than equilibrium speed actual can't requirement is more than provided. This shortage is known as can't deficiency.

$$\boxed{\text{can't deficiency} = X_1 - X_A}$$

X_1 = can't required for higher speed train

X_A = Actual can't provided as per average speed

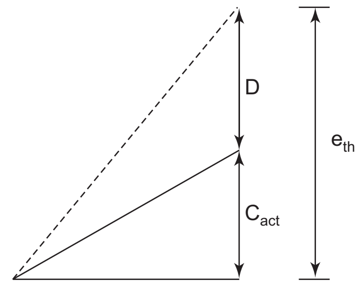


$$\boxed{e_{th} = e_{act} + D}$$

e_{th} = theoretical can't

e_{act} = Actual can't

D = can't deficiency



Limit on D_{max}

	B.G track		M.G	N.G
	< 100kmph	**> 100kmph**		
D_{max}	7.6 cm	10 cm	5.1 cm	3.8 cm

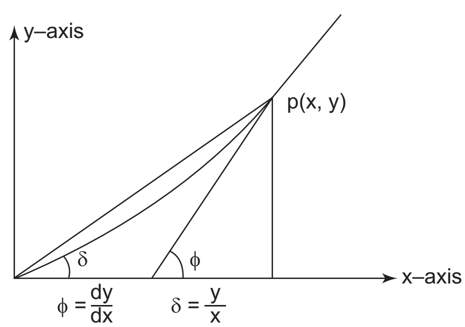
Transition Curve: cubic parabola is used as transition curve.

(i) Equation of deflection $y = \dfrac{x^3}{6RL}$

(ii) Spiral angle $\phi = \tan^{-1}\left(\dfrac{x^2}{2RL}\right)$

(iii) Deflection angle $\delta = \tan^{-1}\left(\dfrac{1}{3}\tan\phi\right)$

(iv) Shift $s = \dfrac{L^2}{24R}$



Note: Transition curve are early set out by offset method.
Cubic parabola is also known as Froude's curve.

Length of transition curve

I approach

$$L = \max \begin{cases} 7.2e \\ 0.03e\,V_{max} \\ 0.073D\,V_{max} \end{cases}$$

E = S.E in cm

D = can't deficiency in com

V_{max} in kmph

II approach

Maximum of the following

(i) Railway board formula

$L = 4.4\sqrt{R}$

L, R → m

(ii) Change of radial acceleration

$$L = \frac{3.28V^3}{R} \quad V \rightarrow \text{m/sec}$$

(iii) Rate of change of super elevation

L = 3.6e

Maximum speed based on length of transition curve

Speed < 100 kmph

$$V_{max} = 134\frac{L}{e}$$

L→m

e → mm

speed > 100kmph

$$V_{max} = 198\frac{L}{e}$$

Gauge widening on curves

$$W_e = \frac{13(B+L)^2}{R}$$

B- Rigid wheel base in meters

For BG = 6m For MG = 4.88m

R-Radius of curve (in m)

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

L = Lap of flange

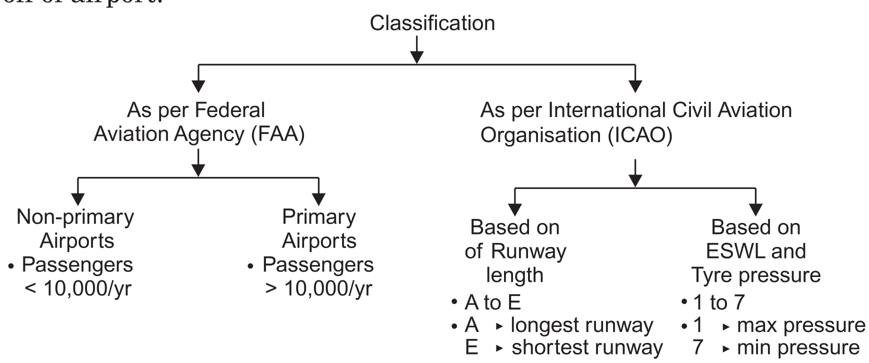
h = depth of wheel flange below rails in cm

D = Diameter of wheel in cm

W_c = Widening of gauge in cm

1 Airport

Airport is an area which is to be regularly used for landing and take off of airport.



Aircraft Components

(*i*) **Engine:**

(*a*) **Piston Engine:** For moderate speeds at low altitudes

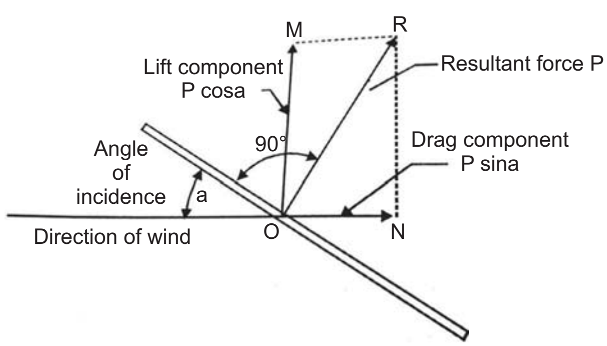
(*b*) **Turbo Jet:** For Higher altitude and greater temperature difference.

(*c*) **Turbo Prop:** At low as well as high altitude.

(*d*) **Ram Jet:** No moving parts, operates at high speed

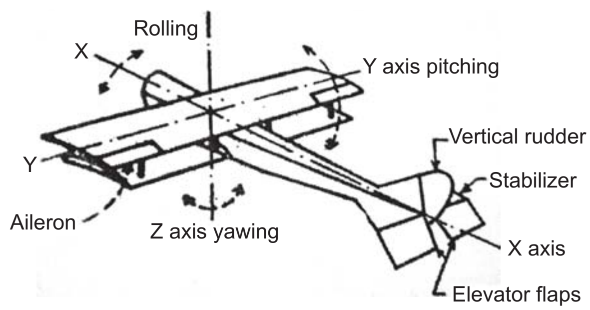
(*e*) **Rocket Engine:** No limit on altitude

(*ii*) **Wings:**



(*iii*) Three Controls:

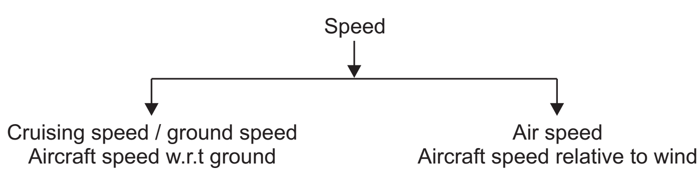
Controller	Used for
Elatator	Pitching
Rudder	Yawning
Aileron	Rolling



(*iv*) Fuselage: It's the main body part of aircraft

Minimum turning radius: Distance of farther wing tip from the centre line of rotation.

Minimum circular radius: Minimum radius with which the aircraft can turn in space.



Maximum Ramp weight > Maximum take off weight > Maximum landing weight

Jet blast: Cement concrete pavement is provided at least at the touch down portion as the bituminous pavement gets affected by the jet blasts.

Noise: Noise foot print recommended is 1 km^2 for 90 *PN dB* and 3 km^2 for 80 *PN dB* (Perceived Noise decibel)

2 Airport Planning

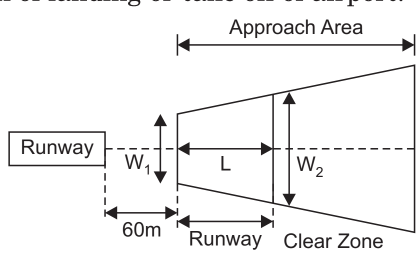
Factors affecting Airport site Selection: Airport use, proximity to other airports, Topography of area, obstruction and visibility, wind (direction, duration and intensity), Noise, Future development, Drainage and soil conditions.

Survey's for site selection: Traffic survey, metrological survey, Topographical survey, soil survey, material survey. Drainage survey.

> **Note:** Most desirable soil with natural drainage conditions contains large amount of **sand and gravels.**

Zoning laws: Laws made in order to prevent future development of obstructions in the vicinity of airport and turning and taking off direction of aircraft.

Approach zone: Wide clearance area required on either side of runway along the direction of landing or take off of airport.



	w_1	w_2	L
Non-Instrument Runway	150 m	270 m	600 m
Instrument Runway	300 m	525 m	750 m

> **Note:** Instrument Runway is equipped with device permitting the landing under condition of poor visibility.

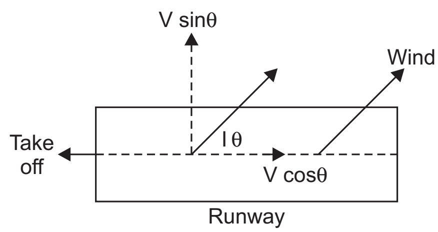
Clear Zone: The inner most portion of approach zone, which is the most critical portion from obstruction point of view.

Turning Zone: The area of airport other than approach zone which is used for turning operation of aircraft. Any object located 4.5 km from runway reference point shall be considered as an obstruction for aircraft turning operation if its height is more than 51 m.

3 Runway Design

Runway orientation: It is oriented such that the direction of wind is opposite to the direction of landing and takeoff. If landing and take off operation are done along the wind direction then longer runway will be required.

Cross-wind component:

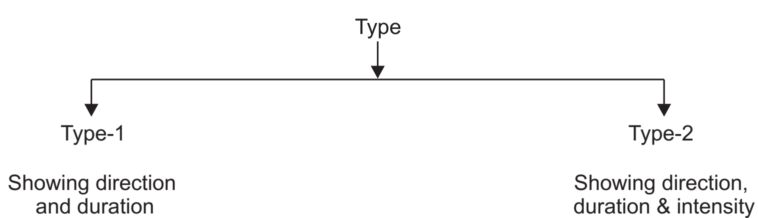


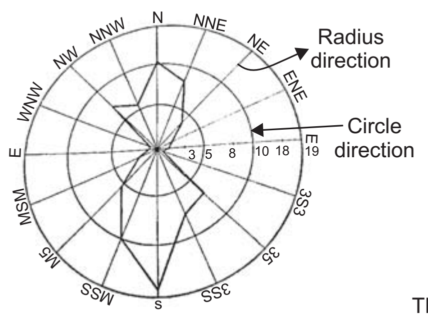
$V \sin \theta$ = Cross wind component

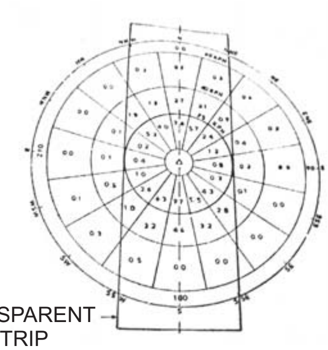
Type of aircraft	*Permissible limit of cross wind component*
Small aircraft	15 kmph
Mixed traffic	25 kmph
Big aircraft	35 kmph

Wind Coverage: The percentage of time in a year during which cross wind component is with in the permissible limits.

Wind rose diagram: It's the graphical representation of direction, duration and intensity of wind. The wind data of atleast 5 years and preferably 10 years is needed for airport deigning.







Radius $\rightarrow$ wind direction
Circle $\rightarrow$ Duration of wind

Radius $\rightarrow$ wind direction
Circle $\rightarrow$ wind intensity
Values entered $\rightarrow$ wind coverage

Note: Calm period is the percentage of time during which intensity is less than 6.4 kmph.

Basic Runway length

Length of runway under following **assumed** conditions

(*i*) Airport at sea level
(*ii*) Temperature at airport is 15°C (standard)
(*iii*) Runway is levelled in longitudinal direction.
(*iv*) No wind blowing on runway.
(*v*) Aircraft is loaded at its full capacity.
(*vi*) There is no wind blowing enroute to destination
(*vii*) Enroute temperature is standard.

Corrections in runway length

(*i*) correction for elevation:

$$L' = L \times \frac{7}{100} \times \frac{E}{300}$$

$L_1 = L + L'$
$E \rightarrow$ elevation from MSL (m)
$L \rightarrow$ Basic runway length
$L' \rightarrow$ Correction due to elevation
$L_1 \rightarrow$ Corrected length

(*ii*) Correction for temperature:

Standard temp = 15 – 0.0065 (E)

Reference temp = $T_a + 1/3\,(T_m - T_a)$

T_a = Monthly mean of average daily temperature of hottest month

T_m = Monthly mean of maximum daily temperature.

ΔT = Reference temp – Standard temp.

$$L'' = L_1\,\Delta T \times \frac{1}{100}$$

$$L_2 = L_1 + L''$$

L'' = Correction due to temperature

L_2 = Corrected length after temperature correction.

Cheek: $\dfrac{L_2 - L}{L} \times 100 < 35$

(*iii*) Correction for Gradient:

$$L''' = L_2 \times G \times \frac{20}{100}$$

$$L_3 = L_2 + L'''$$

G = Gradient in%

L''' = Correction due to gradient

L_3 = Final runway length

> **Note:** ICAO does not recommend any gradient correction

Geometric design of Runway

(*i*) **Runway length:** Actual runway length (L_3) depends upon elevation, temperature and gradient.

(*ii*) **Runway width:** Recommended range is 10 m to 45 m. Typical aircraft traffic is concentrated at central 24 m.

(*iii*) **Width of safety area:** Runway width + shoulder on either side + area cleared, graded and drained.

As per ICAO, for Non Instrumental runway minimum width of safety area

(*a*) for A, B, C type = 150 m

(*b*) for D and E type = 78 m

For instrumental runway its 300 m

(*iv*) Length of safety area: 60 m beyond runway at both ends

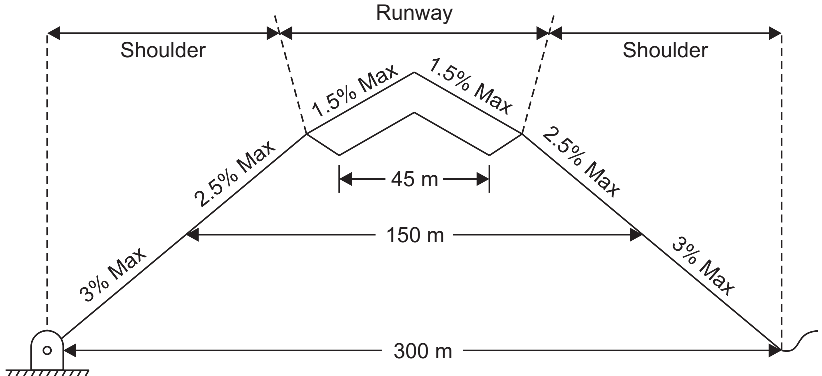
(*v*) Transverse gradient: for proper drainage. AS per ICAO

(*a*) For *A*, *B*, *C* type = Max. Value 1.5%

(*b*) For *D* and *E* type = Max. Value 2%

While minimum value is 0.5% in both above cases

> **Note:** ICAO recommends that upto 75 m from centre its maximum gradient can be 5%



Runway cross-sedion

(*vi*) Longitudinal gradient

(*a*) For *A*, *B*, *C* type = 1.5% max.

(*b*) For *D*, *E* type = 2% max.

(*vii*) Effective gradient

(*a*) For *A*, *B*, *C* type = 1% max.

(*b*) For *D*, *E* type = 2% max.

(*vii*) Rate of change of longitudinal gradient

(*a*) For *A* and *B* type = 0.1% per 30 m length

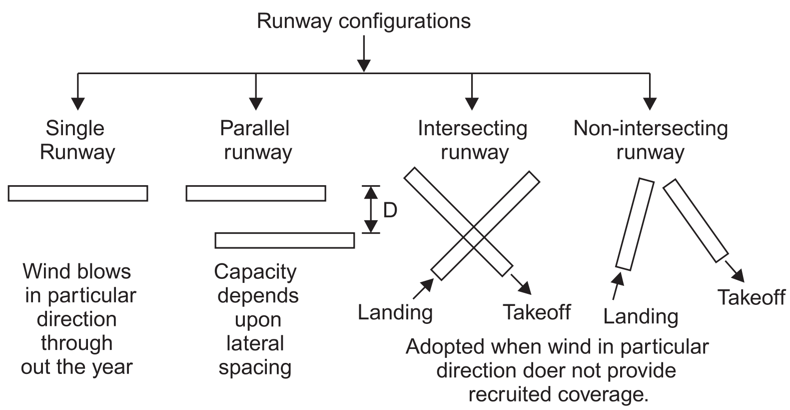
(*b*) For *C* type = 0.2% per 30 m length

(*c*) For D, *E* type = 0.4% per 30 m length

(*viii*) Sight distance: for *A*, *B*, *C* type of airport any two points having 3 m above surface (2.1m above surface for *D* and E type) of runway should be mutually visible from a distance equal to half of runway length.

4 Airport Capacity

Airport Capacity: No. of movements (landing or taking off operation) of aircraft which the airport can safely handle within an hour.



Runway Capacity: (operations/hr or operations/year)

It's the ability of a runway system to accommodate aircraft landing takeoff's. Factors affecting runway capacity are: Air traffic control, demand characterstics, Environmental factors, layout and design of runway system

Gate Capacity: It's an ability of specified no of gates to accommodate aircraft loading and unloading operations under conditions of continuous demand where as gate may be defined as aircraft parking space adjacent to terminal building for loading and unloading of passangers.

Gate Capacity for a single gate = No of aircrafts/minute/gate

$$\text{Capacity}_{\text{single gate}}\ (C_{Sg}) = \frac{1}{\text{Weighted service time}}$$

Capacity of all gates $C = G\ C_{Sg}$

$$\text{Capacity of gate system} = \text{min all}\left[\frac{G_i}{T_i\, M_i}\right]$$

G_i = No of gates that can accommodate aircraft of class i

T_i = Mean gate occupancy time of aircraft of class i

M_i = Fraction of aircraft of class i demanding service.

Taxiway Capacity: It directly affects the runway and gate capacity. It depends on runway operation rate, aircraft mix and location of exit taxiway.

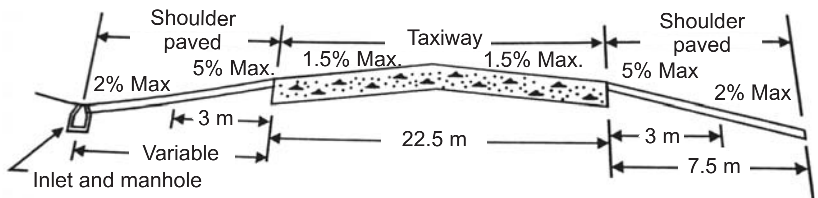
5 Taxiway Design

It provides access to the aircraft from runway to loading apron or service hanger and back.

Factor's effecting geometric design of taxiway:

(*i*) Length of taxiway: As short as possible

(*ii*) Width of taxiway: 22.5 m to 7.5 m



(*iii*) Longitudinal gradient:

(*a*) for *A*, *B* type: max 1.5%

(*b*) for *C*, *D*, E type: max 3%

(*iv*) Transverse gradient: for *A* and *B* type its max value is 1.5% and minimum is 0.5%

(*v*) **Rate of change of longitudinal gradient**

(*a*) for *A*, *B*, *C* type = 1% in 30%

(*b*) for *D*, *E* type = 1.2% in 30%

(*vi*) Sight distance:

(*a*) for *A*, *B*, *C* type: Surface should be visible from 3 m height at 300 m distance

(*b*) for *D*, *E* type: Surface should be visible from 2.1 m height at 250 m distance

(*vii*) Turning radius

(*a*) Radius of the curve $$R = \frac{V^2}{125\,f}$$

R = radius (m)

V = velocity (kmph)

f = Transverse friction coefficient (0.13) (*b*) By Horonjeff's equation

$$R = \frac{0.388\, W^2}{\frac{T}{2} - S}$$

W = wheel base of aircraft in m (16 m – 18 m)
T = width of taxiway pavement (std = 22.5 m)
S = distance *b/w* midway point of the main gear and edge of taxiway pavement in m

$$S = 6 + \frac{\text{Tread of main loading gear}}{2}$$

(*c*) Absolute minimum turning radius regardless of speed

1. for subsonic jet = 120 m
2. for supersonic jet = 180 m

Minimum radius of taxiway will be the maximum of *a*, *b*, *c* discussed above

Exit taxiway

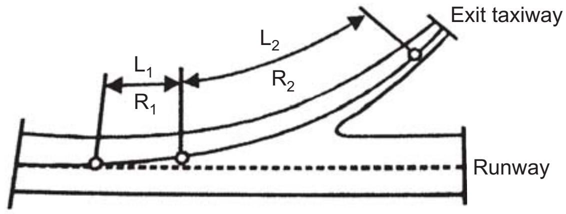
Taxiway located at various points such that landing aircraft leaves the runway as early as possible. Location of taxiway depends upon

(*i*) Number of exit taxiway
(*ii*) Exit speed
(*iii*) Weather condition
(*iv*) Topographic feature.

Design of exit taxiway: At high turn off speeds of 65 kmph to 95 kmph, a compound curve is necessary to minimise the tire wear on the nose gear so, the main radius curve R_2 should be preceded by a larger radius curve R_1 as shown. Aircraft path approximates **a spiral**

$$L_1 = \frac{V^3}{45.5\, CR_2} \qquad C \simeq 0.39$$

$$\text{Stopping distance} = \frac{V^2}{25.5\, d} \qquad d = \text{deceleration}$$



Apron: Paved area for parking of aircraft as well as for loading and unloading the passenger and cargo

Size of apron depends upon

(*i*) **Size of loading area:** i,e gate size

(*ii*) **Number of gate position:** It's the runway capacity in unit of movement per hour

$$\text{Number of gate position} = \frac{\text{Capacity of Runway}}{60 \times 2} \times \text{Average gate occupancy time}$$

(*iii*) **Aircraft parking system:**

(*a*) Frontal system

(*b*) Open area system

(*c*) Finger system

(*d*) Satellite system

Note: Holding apron is the storage area for waiting of aircraft before take off generally provided at busy airports.

Hanger: It's the covered area for repair and servicing the aircraft.