UNIT IV

AIRPORT DESIGN:

Runway Design:

INTRODUCTION:

* Runway design is Planning for a Pattern and arrangement of runways.

* Components of runway design are runway orientation, wind coverage. Orientation is the position or direction of runway.

* coverage is the percentage of time in a year during which a runway could be Put into use. Runway is designed by drawing wind rose diagrams.

* Wind rose diagram is one in which the direction, duration and intensity of wind at a selected airport site is represented to scale.

Elements of Geometric Design of runways:

* Runway length
* Runway width
* Width & length of safety area
* Transverse gradient
* Longitudinal & effective gradient
* Rate of change of Long, gradient

* Sight Distance.

Orientation of runway:

Orientation is positioning of runways. It is usually along prevailing wind direction.

Landing and taking off operations takes place in head wind. It takes place in directions opposite to head wind.

When landing operations take place against wind direction, the head wind Provides a braking effect to aircraft and they come to a stop in a smaller length of runway.

When aircrafts take off, the head wind provides greater lift on wings of aircraft and enables it to rise above the ground within a shorter length of runway.

Therefore a runway is oriented in headwinds.

Wind data interms of direction duration and intensity for the selected site is collected for 5 to 10 years.

These factors impart orientation of runways.

Cross wind component:

centre line of a runway is oriented along prevailing wind direction.

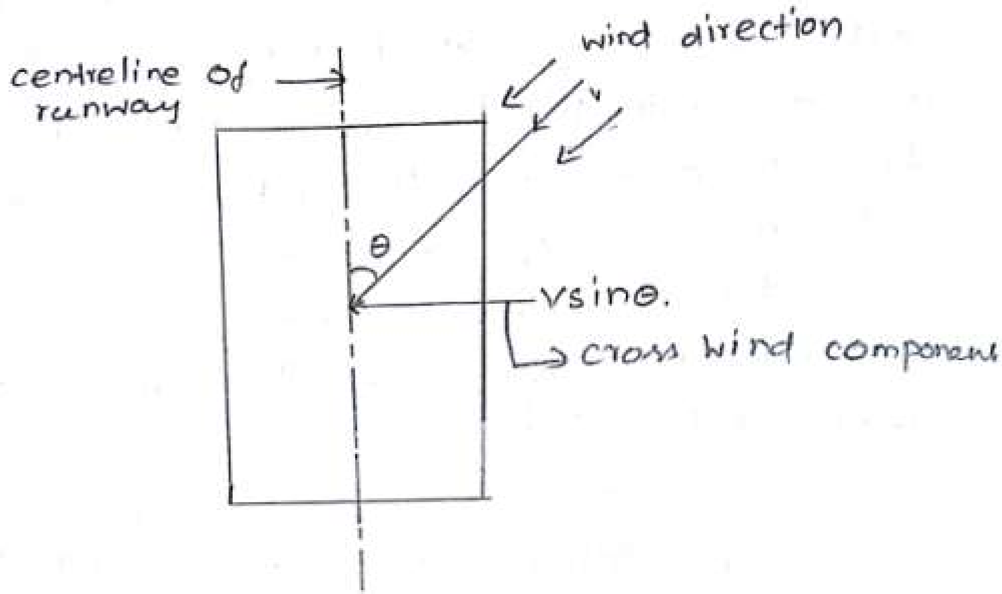
However it is not possible to obtain the direction of wind along the centre line of runway throughout a year.

On some days of a year and few hours of a day, wind may blow making certain angle with a centre line of runway. If an angle b/w the centre line of runway and direction of wind is θ, the component along the direction of runway is $V\cos\theta$, the component normal to the runway is $V\sin\theta$. Where V is wind velocity.

The normal component of the wind is termed as cross wind component. The cross wind component is very dangerous and may interrupt safe landing and take off operations. As per ICAO, the following are permissible cross wind component

Airport/Aircraft Type	cross wind component (velocity)	Field length
Small Aircrafts	14 - 24 km/hr	< 1200 m.
Mixed Traffic	25 - 37 km/hr	1200 to 1500 m
Big Aircrafts	> 37 km/hr	≥ 1500 m.

cross wind component:



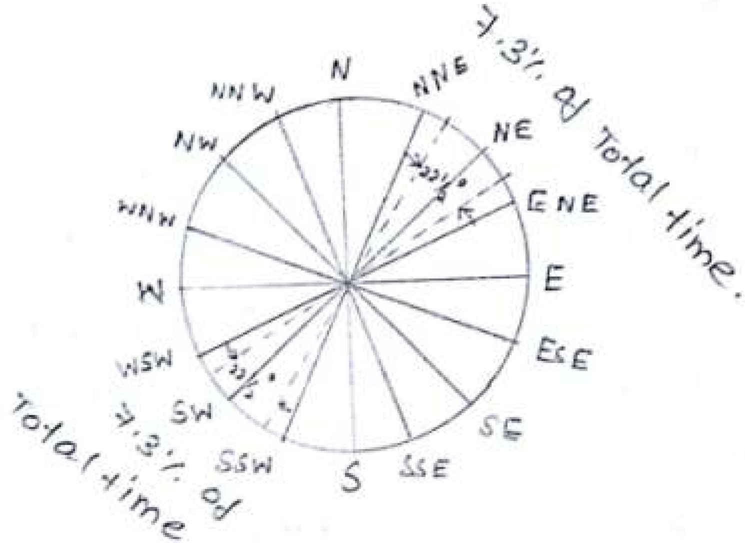
wind coverage:

Coverage is the percentage of time in a year during which a cross wind component remains within permissible limits.

For purpose of calculating coverage, an assumption is made to effect that a deviation in a direction upto

22.5° + 11.25° from directions of landing and take off operation is permissible.

For example if 'NS' is the best orientation, the coverage for orientation is obtained by summing up durations in the directions of N, NNE, NNW, S, SSE & SSW.



Wind directions and coverage.

Calm period:

Percentage of time in a year during which wind intensity is less than minimum intensity is termed as calm period.

It is assumed that during calm period, intensity of wind is negligible and do not interfere with landing &

Take off operations.

∴ The calm period is added to the calculated wind coverage.

Wind rose diagram - Type I:

i) Determination of orientation of runway:

* Past wind data for a selected site of an airport is collected for as many years as possible.

* Data should be collected atleast for 5 yrs & preferably for 10yrs.

* Average data is obtained with sufficient accuracy.

* Since wind data is vary considerably from site to site, observations should have been taken at or near a site selected as far as possible.

ii) Direction and duration:

* Radial lines indicate wind directions.

* Avg. wind data are obtained for 16 directions

* Each direction covers an angle of $22.5°$.

* It is assumed that wind may blow from any point within 22.5°

iii) Best orientation of runway:

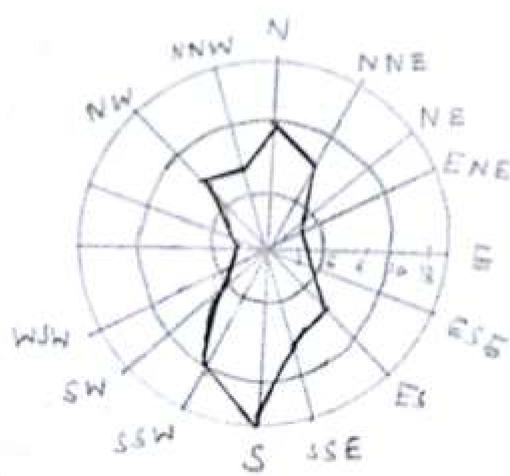
values of durations from wind data are marked in respective durations

The best orientation of a runway is usually along the direction of the longest line in wind rose diagram.

iv) Wind Coverage:

It is assumed that deviation of direction is permissible is upto 33.75°.

Percentage of time during which a runway can be used for landing & take off in this ex. is obtained by summing percentages of time along NNW, N, NNE, SSE, S, SSW.



Procedure to determine the orientation:

1) Draw three Parallel lines on a transparent paper at the equal distance apart. The distance b/w Parallel lines is equal to Permissible cross wind component. It is drawn to the same scale with which the wind rose diagram. cross wind componen is 25 km/hr.

2) Place a transparent paper over the wind rose diagram in such a way that its centre lies over the central line of wind rose diagram.

iii) with the centre of wind rose, rotate the tracing paper and place it in such a position that the sum of all values of duration of a wind, bound by two outer parallel lines has a maximum value. Thus the direction indicated by the central line is the orientation of runway. Wind coverage is calculated by adding up all percentage of duration shown in segments. The percentage of duration is assumed to be equally distributed over the entire area of segments. If outer parallel lines of transparent strip cross a segment, proposed value is assessed and added.

Second runways:

Runways handling mixed air traffic should be planned so that they coverage is more than 95%.

Airports should be operational atleast for 95% of the time in a year. For busy airports the wind coverage may be increased upto 100%.

However this may be possible only by planning for second & more runways.

orientation of the second runway is the second longest direction in the wind rose diagram.

While calculating additional coverage for the second runway, duration of any direction, already added for the first runway should not be added for second time.

Example 1,

Table below shows a typical wind data for an airport site. Determine the best orientation of the runway and percentage of time during which the runway can be used. Does it require a second runway? If so Determine Total coverage.

Wind direction	Percentage of time		
	6-25 km/h	25-50 km/h	50-80 km/h
N	4.60	1.40	0.10
NNE	3.40	0.75	0.00
NE	1.80	0.03	0.10
ENE	2.80	0.02	0.03
E	2.10	0.20	0.00
ESE	5.40	4.75	0.00
SE	6.40	1.40	0.00
SSE	7.50	0.02	0.00

Wind direction	Percentage of Time		
	6-25 kmph	25-50 kmph	50-80 kmph
S	4.60	1.40	0.10
SSW	2.40	0.75	0.00
SW	1.20	0.03	0.10
WSW	3.60	0.03	0.02
W	1.70	2.30	0.00
WNW	6.00	4.75	0.00
NW	5.90	1.40	0.00
NNW	6.80	4.90	0.30

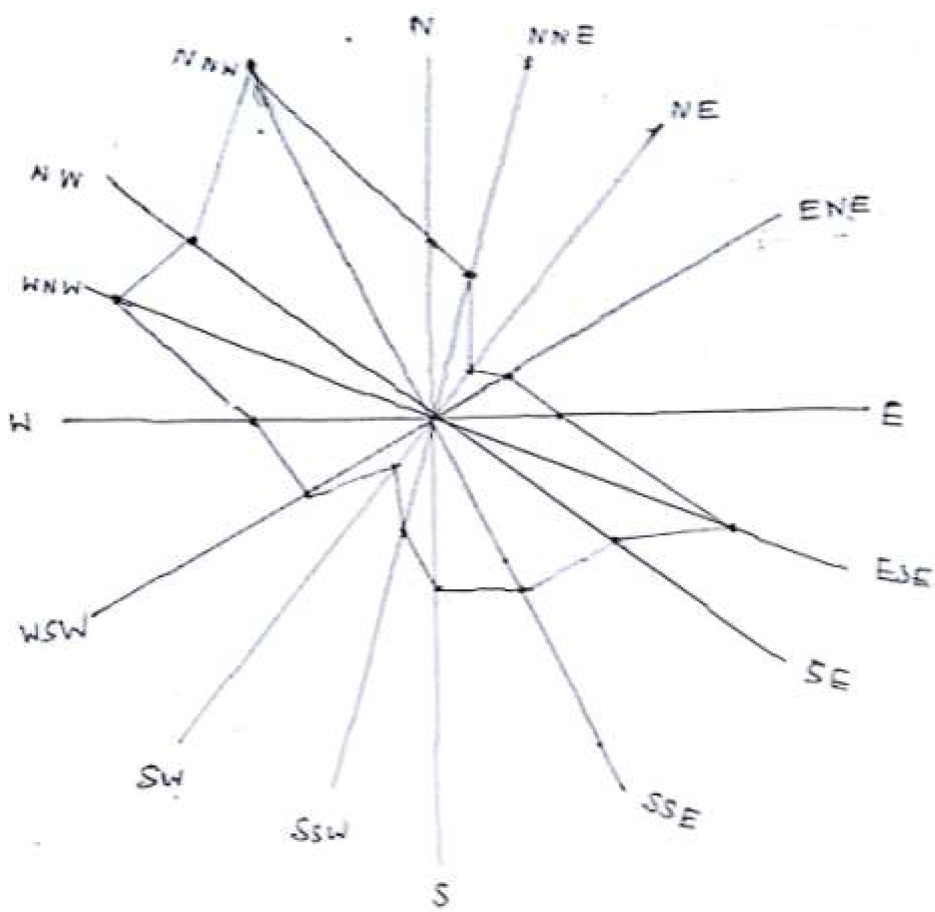
Soln:

Wind direction	Percentage of time
N	6.10
NNE	4.15
NE	1.93
ENE	2.35
E	3.20
ESE	10.15
SE	7.20
SSE	7.5
S	6.10
SSW	3.15
SW	1.33
WSW	3.65
W	4.00
WNW	10.75
NW	7.30
NNW	12.00

Percentage of wind blow = 92.08

Calm Period = 100 − 92.08

= 7.92



Best orientation = NW − SE

Total Period of operation = SSE + SE + ESE + NW + WNW + NNW + calmperiod

= 7.52 + 7.80 + 10.15 + 7.3 + 10.75 + 12 + 7.92

coverage = 63.44.

The landing and take off operations in the airport can take place on the runway only for 63.44% of time in a year. However the percentage is on lower side. ∴ there is need to design a second runway.

Best orientation for a second runway is the second longest line on the wind rose diagram.

orientation for the second runway is WNW-ESE

coverage for II runway = WNW + NW + W + ESE + E + SE

(X) coverage of any direction should not be added for the second time.

coverages for SE, ESE, NW, WNW have already been added.

The coverage for E & W can be added.

ie) 3.30 + 4.00 = 7.30

∴ Total coverage with the second runway

= 63.44 + 7.30 = 70.74 %

Basic runway length:

Basic runway length is the length of runway under following condition of an airport.

* Altitude of an airport @ sea level.
* Airport has standard temperature (15°C)
* Runway has no longitudinal gradient
* wind doesnot blow on the runway.
* Airport is loaded to its full capacity,
* wind doesnot blow en-route to
* destination
* Enroute temperature is standard

Basic runway length is determined based on aircraft Performance. Normally following cases are considered

* Normal landing case
* " Take Off "
* Engine Failure case.

Actual runway length:

i) corrections for elevation, Temperature, Gradient:

Ideal conditions for an airport is not possible in real world conditions.

In most cases, elevation of airports may not be at mean sea level they may not have std. atmospheric condition

corrections may be required for actual sites of airports for change in elevation, temperature and gradient.

Corrections for Elevation:

* Air density reduces with increase in elevation. This is turn reduces lift on wings of aircrafts.

* So longer runways are required

* The basic runway length has to be increased by 7 %. for every 300m rise in elevation above Mean sea level.

Correction for Temperature;

Airport Reference Temperature is the sum of monthly mean of average daily temperature (T_a) and the monthly mean of max. daily temperature (T_m) for same month of the year.

$$\text{Reference Temperature} = T_a + \left(\frac{T_m - T_a}{3}\right).$$

As per ICAO recommendations, the basic runway length has to be increased at a rate of one percent for every one degree rise of an airport reference Temperature above standard atmospheric temperature of that elevation. Temperature gradient of std. temperature from mean sea level to an altitude at which temperature becomes 15°c is 0.0065°c / metre. The temperature gradient becomes zero above an altitude with std. Temperature of 15°c.

Check for Total correction for elevation plus Temperature:

ICAO recommended that if total correction for elevation plus temperature exceeds 35% of basic runway length, the correction further checked up by conducting specific studies at the site by model Tests.

Correction for Gradient.

Steeper gradients require longer runway.

A runway length needs to be increased, incase of longitudinal gradient.

The runway has to be increased at a rate of 20% for every 1% of effective gradient.

Effective Gradient:

It is defined as the maximum difference in elevation b/w the highest and lowest points of runway / unit length of runway.

Actual runway length:

Actual runway length is the corrected length of the runway for actual elevation, temperature and gradient. All these corrections are positive. ∴ Actual runway is longer than Basic runway.

Examples:

Monthly mean of average daily temperature for the hottest month of year at an airport site is 40°c. Monthly mean of maximum daily temperature for the same month of the year is 50°c. calculate the airport Reference Temperature if the site is at MSL with a level ground. Determine the actual runway length to be provided.

Mean of max. daily Temperature, T_m = 50°c

Mean of avg. " " , T_a = 40°c

$$ART = T_a + \left(\frac{T_m - T_a}{3}\right)$$

$$= 40 + \left(\frac{50-40}{3}\right) = 43.33\,^\circ c.$$

Std. atmospheric temperature at MSL = 15°C

Rise in temperature = [illegible] − 15 = [illegible]

Correction = 1% per 1°C rise in temperature

Assume basic runway length as 1 meter

∴ Required correction = $\frac{1}{100}$ × [illegible] = [illegible]

The runway is at MSL ∴ Actual length of runway = 1.[illegible] times the basic runway length

Example 2:

Length of a runway at MSL, standard temperature and zero gradient is 1600m. The site has an elevation of 320m, with a reference temperature 33.6°C. The runway has to be constructed with an effective gradient of 0.25%. Determine the actual length of the runway at site.

Soln:

Std. length = 1600m

Elevation of site = 320m

Ref. Temperature = 33.6°C

Effective gradient = 0.25%

correction for elevation :

Increase in length = 7% for every 300m elevation

$= \frac{7}{100} \times \frac{320}{300} \times 1600$

$= 119.47$ m.

corrected length = 1600 + 119.47 = 1719.47 m.

correction for temperature

1% for every 1°c increase,

Ref. Temperature = 33.6°c.

Std. Temperature at site = 15 − 0.0065 × Elevation

= 15 − 0.0065 × 320

= 12.92°c

Difference in Temp = 33.6 − 12.92 = 20.68°c

Increase in length $= \frac{1}{100} \times 20.68 \times 1719.47$

= 355.59m

corrected length = 355.59 + 1719.47

= 2075.06m

check for total correction of elevation & Temperature

$= \frac{2075.06 - 1600}{1600}$

= 29.68%

It must be less than 35% as per ICAO standards.

correction for gradient:

20% for every 1% Effective gradient

$$\frac{20}{100} \times 0.25 \times 2075.06 = 103.75 \text{ m}$$

corrected length = 2075.06 + 103.75 = 2178.81m

Runway Geometric Design elements

i) Airport Reference codes:

The ARC composed of two elements. Element 1 is a number based such on Aircraft reference field length. Element 2 is based on aircraft wing, span, outer main gear wheel span.

ARC

Code Element 1		Code Element 2		
Code NO	Aircraft Reference field length	Code letter	wing span	Outer main gear wheel span
1	Less than 800m	A	Less than 15m	Less than 4.5m
2	800 - 1200 m	B	15m to 23.9m	4.5m - 5.9m
3.	1200 - 1800 m	C	24 - 35.9m	6 to 8.9 m
		D	36 - 51.9m	9 to 13.9m
4	More than 1800 m	E	52 - 64.9m	9 to 13.9m

Runway length:

ACTUAL LENGTH OF PRIMARY RUNWAYS:

Length should be adequate for operational requirements of aircrafts for which a runway is intended. It should not be less than the longest length determined by applying corrections.

ACTUAL LENGTH OF SECONDARY RUNWAYS:

It is determined in the same way as that of primary runway. It needs to be adequate both for those aircrafts which require to use the secondary runway in order to obtain a usability Factor of 95%.

Runway Width:

width of runways for different class of airports

code NO	code letter				
	A	B	C	D	E
1[a]	18 m	18 m	23 m	–	–
2[a]	23m	23 m	30m	–	–
3	30m	30m	30m	45m	–
4	–	–	45m	45m	45 m

Longitudinal gradient :

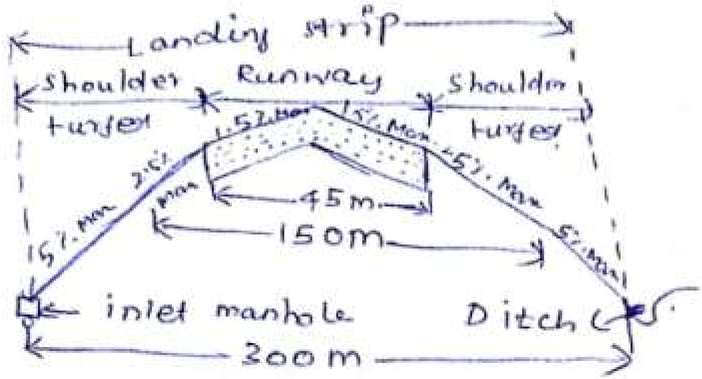
Sudden or abrupt change of longitudinal gradient is undesirable. Such a gradient may restrict height distance and cause premature lift of aircraft during take off operations. Premature lift affect performance of aircrafts and may develop structural defects.

Code No	Maximum longitudinal Gradient	Rate of change.
1 or 2	2%	2%
3 or 4	1%	1.5%

Transverse gradient.

Class of Airport	Transverse gradient	Remarks
A, B	2%	Transverse gradient is for runway should be same throughout the length of runway except at an intersection with another runway or taxiway.
C, D, E	1.5%	

code NO	Rate of change of Transverse gradient	Remarks
4	0.1%/30m	min. radius curvature 30,0000
3	0.2%/30m	" " " 15000
1.2	0.4%/30m	" " " 7500m



SIGHT DISTANCE:

Type of Airport	condition for sight distance
C, D & E	Any point 3m above the surface of a runway should be mutually visible from a distance equal to half the runway length.
B	There should be an unobstructed length line of sight from any point, 2m above a runway, and to all other points, 2m above the runway within a distance of atleast one half the length of runway
A	There shall be an obstructed line of sight from any point 1.5m above the runway to all other points 1.5m above the runway within a distance of atleast half the length of runway.

STRENGTH OF RUNWAYS:

A runway should be capable of withstanding aircrafts the runway is expected to carry.

SURFACE OF RUNWAYS:

* It shall be constructed without irregularities
* otherwise, it should result in loss in friction characteristics & thereby adversely affect landing and take off operations.
* When the surface of runways are grooved, the grooves should be perpendicular to runway centre lines.

RUNWAY SHOULDERS:

* shoulders are provided for runways where the code letter is D & E & the runway width is less than 60m.
* The surface of a shoulder should be flush with the surface of the runway & its transverse slope should not exceed 2.5%

A runway shoulder should be capable to

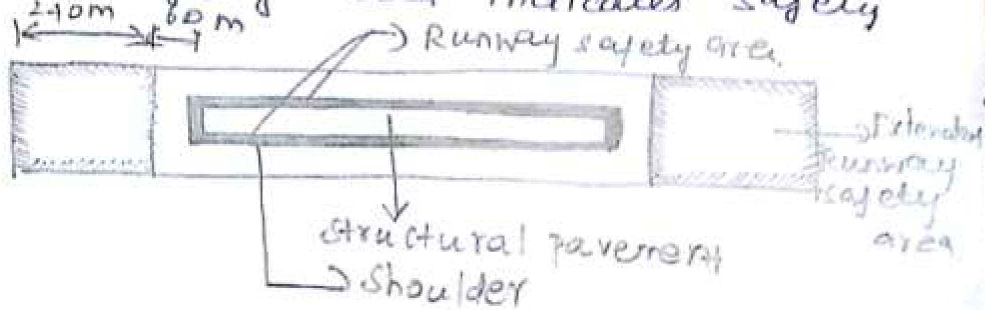
* support an aircraft in the event of the aircraft running off the runway.

* support ground vehicles when they operate on them.

* shoulders are provided with steeper gradient to facilitate effective drainage.

RUNWAY SAFETY AREA:

components of runway safety area are the runway, shoulders on either side of runway, and the area that are cleared, graded and drained. As the name itself indicates, safety area indicates safely

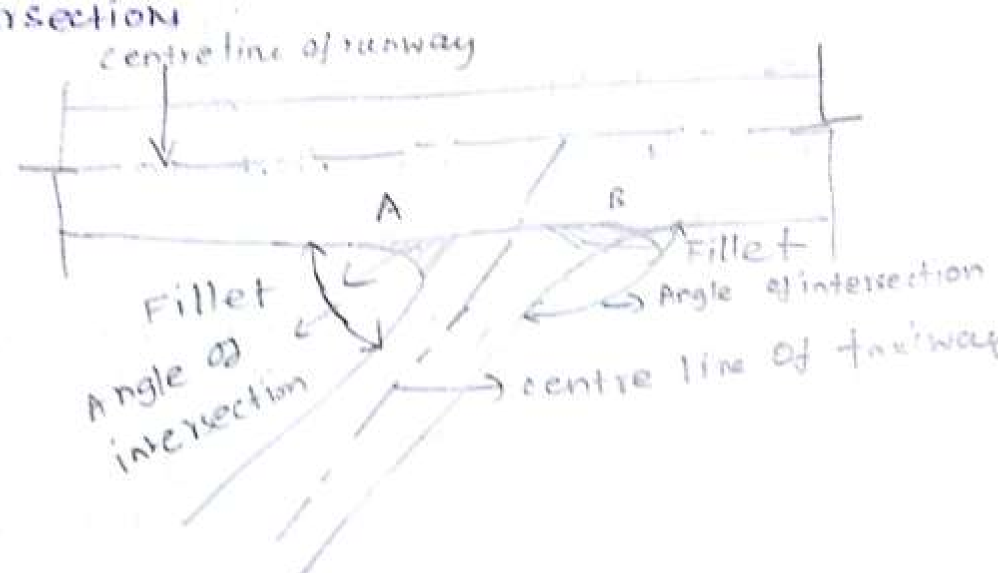


FILLETS JUNCTIONS/ INTERSECTIONS:

* It refers to small space laid at the junction of two parts at right angles to each other.

* The junction of taxiway and runway provided with corner fillets. It provides a smooth curve.

* It is provided @ junctions to ensure minimum wheel clearances when aircrafts manoeuvre through junctions & intersection



Runway Pavement Design:

i) Runway & highway Pavement characteristics:

Requirements of runway Pavements are different from that of highways.

Besides heavy dynamic wheel loading of aircrafts, runways have to weather special problems such as fuel spillage, heat and blast of engine exhausts, high type pressure and small contact area.

Effect of fuel spillage, heat & blast loosen pavement particles & this is hazardous to aircrafts.

This phenomena leads to sudden change in longitudinal grade and in Pavement undulations.

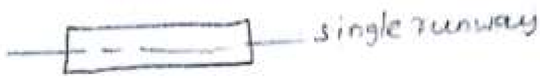
The repetitive load in narrow band along centre line of taxiway cause rutting.

Runway Pavement Design

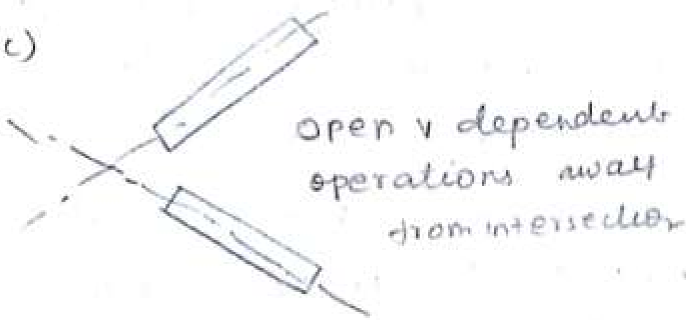
RUNWAY CONFIGURATION:

It refers to shape or arrangement of runways. They may be parallel or intersecting.

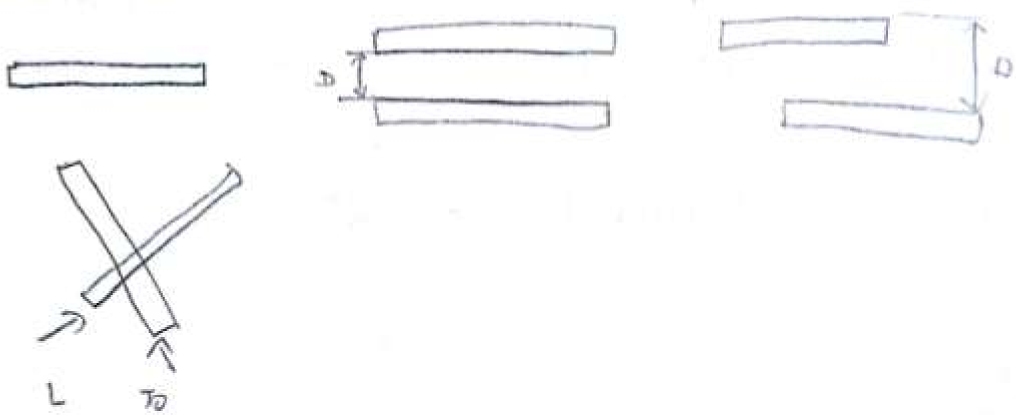
RUNWAY CONFIGURATION:

a) 

b) 

c) 

RUNWAY BASIC PATTERN:



Airport classification	Taxiway width	Max. Long. gradient	Max Transverse gradient	Max. rate of change of long. gradient (%)
E	23m	1.5%	1.5%	1% per 30m (Min. R.O.C 3000m)
D	18 to 23m	1.5%	1.5%	"
C	15 to 18m	1.5%	1.5%	1% per 30m "
B	10.5 m	3%	2%	1% per 20m (Min. R.O.C 2500m)
A	7.5 m	3%	2%	1% per 25m (Min. R.O.C 2500m)

~~Taxiway~~ curves:

RUNWAY DRAINAGE:

* Drain pipes should be stronger enough to withstand heavy and dynamic wheel load of aircrafts

* crushing of Pipes may be hazardous to aircrafts.

special characteristics of runway drains are

1) Heavy concentrated & dynamic wheel loads
2) wider runways when compared with highway Pavements
3) Absence of side drains

TAXIWAY DESIGN:

1) Taxiway is the link b/w runways and aprons.

2) It provides access to aircrafts from railways to apron or service hangar & back

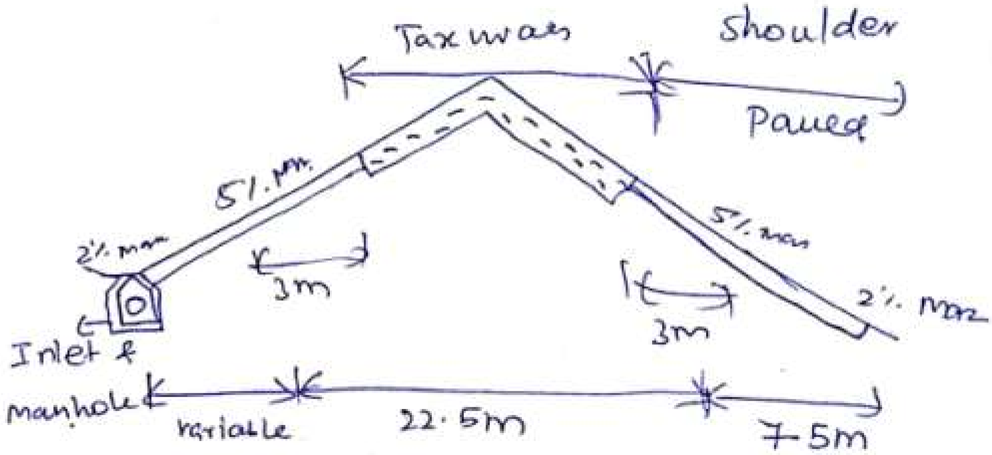
3) Route for a taxiway should be shortest and straight as far as possible

4) Taxiways provide safe and expeditious surface movement of aircrafts when road traffic is high rapid exit taxiways are provided.

Design Elements of taxiways are
i) Length ii) width iii) width of safety area iv) Longitudinal gradient v) Transverse gradient vi) Rate of change of longitudinal gradient vii) sight distance viii) Turning radius.

1) CLEARANCE:

The clearance distance b/w outer main wheel of an aircraft & edge of the taxiway. It is measured when the cockpit of aircraft is over the centre markings of taxiway



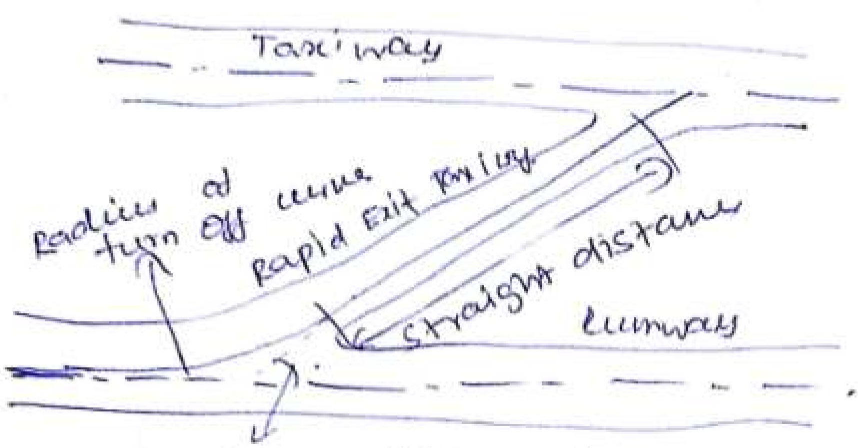
2) Taxiway shoulders:

code letter	Min. overall width of Taxiway & shoulders
C	25 m
D	38 m
E	44 m.

Strength & surface of Taxiways

* strength should be atleast equal to that of runways
* should not have irregularities that cause damage to aircraft structures
* good frictional characteristics when the taxiway is wet

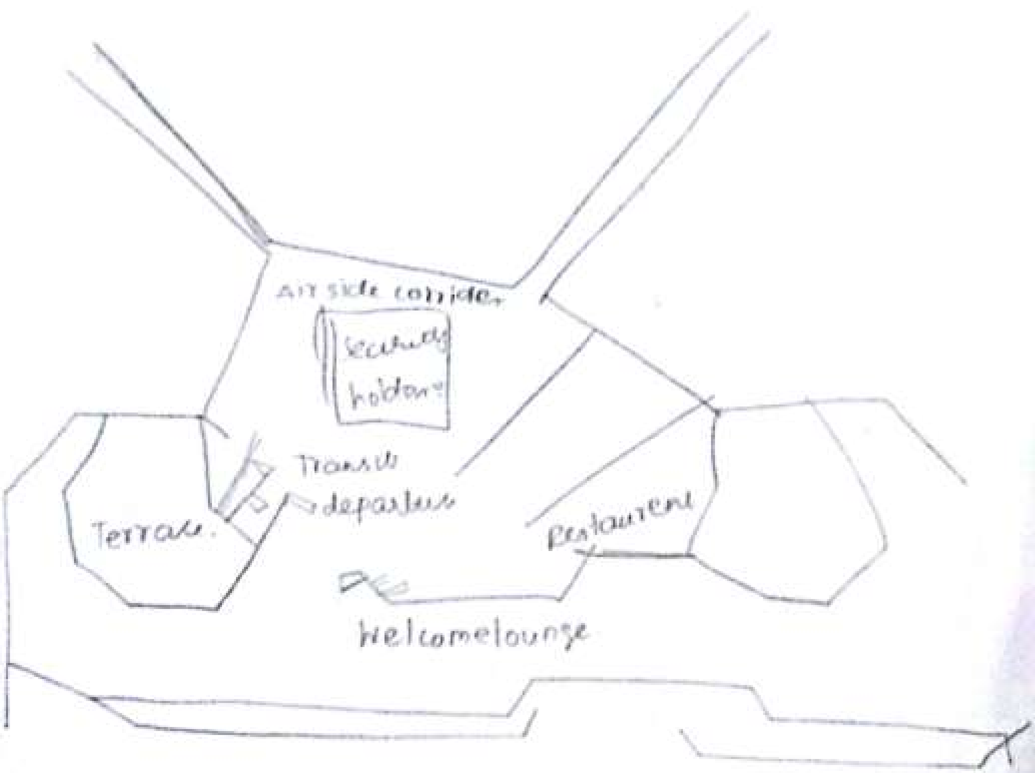
Rapid Exit Taxiways



PASSENGER FACILITIES & SERVICES

i) The general facilities provided in airport

a) Economic lounges to comfortable s(i)
b) Electronic lockers
c) Parent rooms
d) Inter- terminal Transport
e) Arrival hall
f) Departure hall.
g) Medical services
h) Flight information enquiries counter.



Visual aids:

They are apparatuses which support or helps pilots in helping Pilots in sighting various features.

Pilots need aids during landing and take off operations

i) INDICATORS AND SIGNALLING DEVICES:

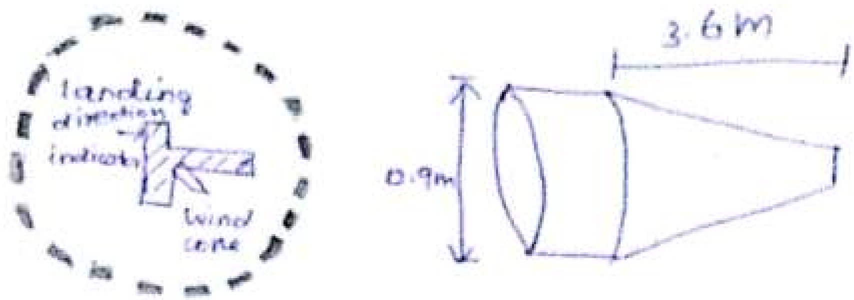
They are wind direction indicators and landing indicators

WIND DIRECTION INDICATOR:

It shows the direction from which wind blows. It may be a wind cone. The wind cone is placed within a segmented circle together with landing directions. This helps to locate airports & wind direction indicator.

LANDING DIRECTION INDICATOR:

It is in the form of 'T' at the centre of sequencing circle. It is to indicate the direction of active runway of airport to pilots



RUNWAY MARKINGS:

a) Runway designation Markings:

It shall be made at thresholds of paved runways. It consists of two digit number. It indicates magnetic azimuth measured clockwise for north direction

b) RUNWAY CENTER LINE MARKING:

It is done on the centre line of runway.