

— ESENOTES.COM —

AIRPORT ENGINEERING



BY JASPAL SIR

TABLE OF CONTENTS

I	Airport	3
II	Airport Planning	5
III	Runway Design	7
IV	Airport Capacity	13
V	Taxiway Design	14
VI	Exit Taxiway	16
VII	Visual Aids & Drainage System	19
	A Airport Making	20
	B Airport Lighting	22
	C Airport Drainage	23
VIII	Heliport	23
IX	Tunnel Engineeing	24

AIRPORT ENGINEERING

AIRPORT



-It is an area which is to be regularly used for landing and take off of aircraft.

-It is provided with all the facilities for shelter, repair of aircraft and for passengers and cargo.

-These can be classified as follows-

(a) **PRIMARY AIRPORT**- which can handle more than 10000 passengers.

(b) **Non-PRIMARY AIRPORT**- which can handle

Less than 10000 passengers.

(c) **AIRPORT A to E**: This classification is on the basis of length of runway, where A type airport has the longest runway and E type has the shortest.

(d) **AIRPORT 1 to 7**- This classification is on the basis ESWL (i.e equivalent single wheel load) and tyre pressure when airport 1 represents maximum ESWL and tyre pressure and 7 represents minimum ESWL and pressure.

BASIC FEATURES OF AIRPORT



(a) FIELD LENGTH



-An aircraft is required to demonstrate the field length required for following cases:-

(i) To complete a take off to 10.5 m altitude with all engines operating.

(ii) To complete a take off to 10.5 m altitude with an engine failure at a critical point.

(iii) To stop after aborting a take off with an engine failure at the same critical point.

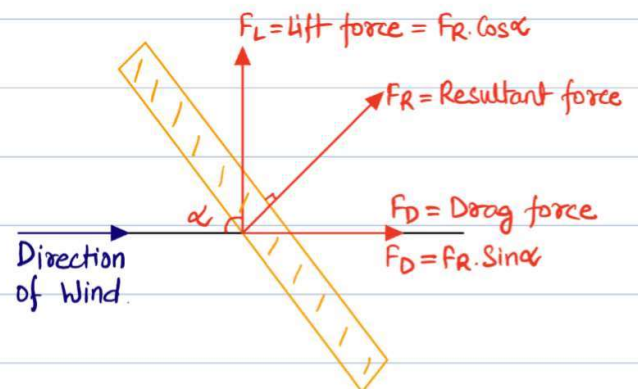
(iv) To stop after landing from a height of

15m.



(b) WINGS

-The purpose of aircraft wing is to support the aircraft in the air.



(c) **THREE CONTROLS** : ROLLING, PITCHING, YAWING.

-Turning of the aircraft about longitudinal axis is termed as ROLLING MOTION.

-It is controlled using AILERON.

-Turning of the aircraft about lateral axis is termed as PITCHING MOTION.



-It is controlled using elevator.

-Turning of the aircraft about 1st/vertical axis is termed as YAWNING MOTION.

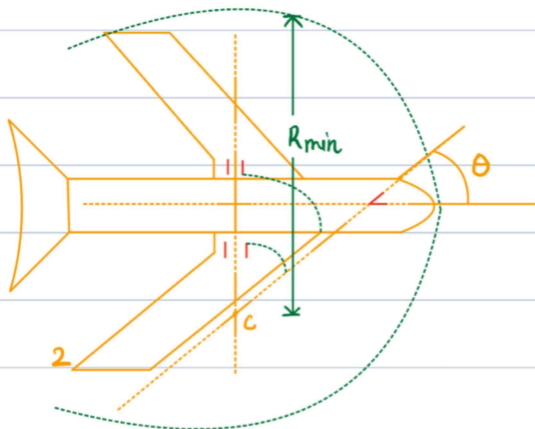
-It is controlled using RUDDER.

(D) FUSELAGE



The main body of aircraft which consist of fuel, passenger, cockpit, cargo etc. is termed as fuselage.

(E) MIN TURNING RADIUS



-For deciding the radius of taxiway, position of aircraft at loading apron and hangar, min turning radius is required.

(F) MINIMUM CIRCULAR RADIUS

-The min radius with which the aircraft can take turn in space.

-It depends on type of aircraft, air traffic volume and weather condition.



(G) SPEED

(i) Ground speed / Cruising Speed : It is aircraft speed wrt ground when aircraft is in air at its maximum speed.

(ii) AIR Speed : It is aircraft speed wrt wind.



(H) WEIGHT COMPONENT

(a) Empty operating weight : It is the constant weight of aircraft.

(b) Zero fuel weight : It is empty operating weight + Maximum payload.

(c) **Maximum take off weight** : It is empty operating weight + combination of payload and fuel.

(d) **Maximum landing weight** : It is maximum take off weight - weight of fuel burned during flight.

(e) **Maximum ramp weight** : It is maximum take off weight + weight of fuel required for taxiing.



AIRPORT PLANNING

(A) AIRPORT SITE SELECTION

(i) **Airport use** : Civilian or military use.

(ii) **proximity to other airports** : No interference in landing and take off.

(iii) **Topography** : Raised grounds.

(iv) **Obstruction and visibility** : It should be least and maximum respectively.



(v) **Wind** : Runway is oriented such that landing and take off is done by heading into the wind.

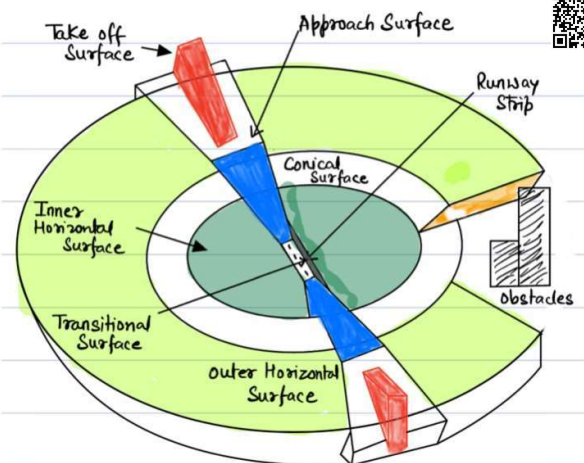
(vi) **Noise** : It must be away from residential development.

(vii) **Drainage and soil properties** : Natural drainage with highly permeable soil.

(viii) **Future development** : Scope for additional runway and facilities.



AIRPORT OBSTRUCTION AND RUNWAY ORIENTATION



1) ZONING LAWS



-These laws are imposed in order to prevent future development of obstructions in the vicinity of airport and turning and take off airport.

-Obstruction to safe air navigation are broadly divided into two:

(a) Object protruding above certain imaginary surface.

(b) Object exceeding their limiting height above the ground surface in approach zone and turning zone

-following are the different components of imaginary surface.

(i) Take off CLIMB SURFACE :

It is established beyond end of runway or clearway for each runway direction.

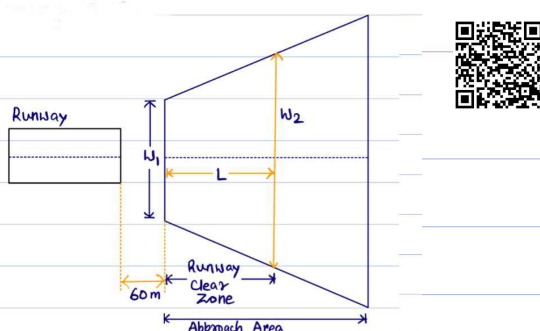


(ii) APPROACH SURFACE :

It is established from the smaller end of the runway strip for each runway direction.

-over this area, the aircraft can safely lose or gain altitude.

-The whole of this area has to be kept free of obstruction using zoning laws.



Type of Runway	W_1	W_2	L
Instrumental Runway	300m	525m	750m
Non-Instrumental Runway	150m	270m	600m
Small Instrumental runway	75m	135m	300m

Note 1: Here instrumental runway is equipped with devices permitting the landing under conditions of poor visibility.



Note 2: Here, the inner most portion of approach zone, which is the most critical portion from obstruction point of view is known as CLEAR ZONE.

(iii) IHS (INNER HORIZONTAL SURFACE):

It is the surface located in a horizontal plane above on AERODROME and its surrounding.

(iv) CONICAL SURFACE :

It extends upwards and outwards from the periphery of IHS.

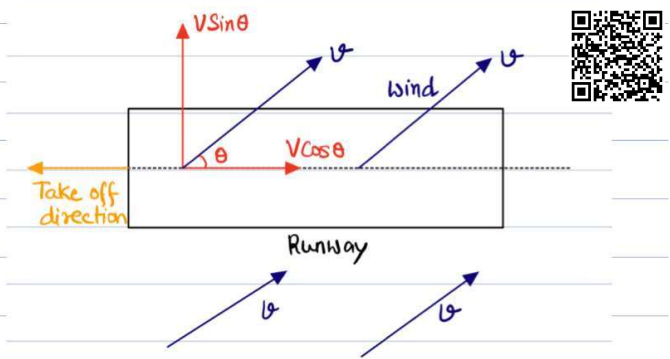


(V) TRANSITION SURFACE :

It is a surface along the soil of the strip and part of the side of approach surface that slopes upwards and outwards to the ILS.

(VI) OHS (OUTER HORIZONTAL SURFACE) :

It is a circular surface in plan with centre locate at APC and with height of 150m.



- It is not possible to obtain the direction of central line of runway through out the year.

- If the direction of wind is at an angle (θ) to the runway centre, its component along the direction of runway ($V \cos \theta$) is termed HEAD WIND COMPONENT and its component normal to the central line of runway ($V \sin \theta$)

is termed CROSS WIND COMPONENT, which interrupt in safe landing and take off operations.

- Its permissible limit are as follows

Type of Aircraft	Permissible ($V \sin \theta$) (Kmph)
Small Aircraft	15
Mixed Aircraft	25
Big Aircraft	35

- Here the % of line in a year during which cross wind component is within permissible limit as speci-

RUNWAY DESIGN

- In order to design the runway, its first fixed.

- Runway is usually oriented in the direction of prevailing wind i.e the direction of wind opposite to the direction of landing and take off.

- The head wind provides greater lift force on the wing of aircraft when it is taking off and also provides braking effect to the aircraft so that runway length required is less.

fied above is called WIND COVERAGE.

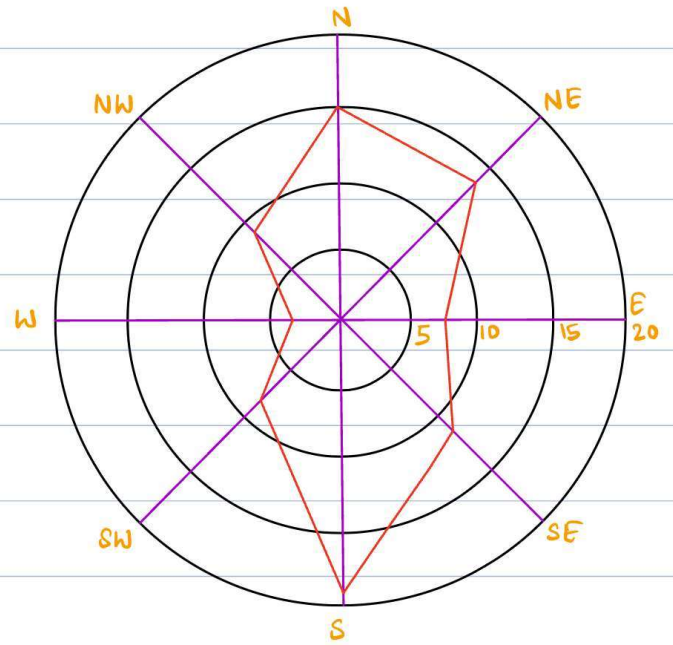
-According to FAA, runway landing mixed air traffic should be planned that wind coverage is 95% and permissible cross wind component should not exceed 25 Km/h.



WIND ROSE

-The graphical representation of wind data i.e. DIRECTION, DURATION, INTENSITY is called WIND ROSE.

-The wind data of at least five years and preferable of 10 years should be considered while designing the airport.



-Wind rose is used for orientation of runway.

-Wind rose can be plotted in two ways :



(a) Type I : SHOWING DIRECTION AND DURATION OF WIND

-Here the radial lines indicate the wind direction and each circle represents the duration of wind.

-The best direction of runway is along the direction of longest line on wind rose.

Type 2 : SHOWING DIRECTION AND INTENSITY OF WIND

-Each circle represents the wind intensity, radial lines represent the direction and the values entered in each segment represent the percentage of time in a year during which wind blows.



BASIC RUNWAY LENGTH

-It is the length of runway under the following assumed condition.

(a) Airport altitude is at sea level
(All sea level $T = 15^\circ\text{C}$, $P = 760\text{ mm of Hg}$, $\rho_{\text{air}} = 1.225\text{ Kg/m}^3$)

(b) Temperature at airport is standard (15°C).

(c) Runway is levelled in longitudinal direction.

(d) No wind is blowing on runway.

(e) Airport is loaded its full capacity.

(f) There is no wind blowing enroute to destination.

(g) Enroute temperature is standard (15°C).

-The basic runway length is determined in three following case.

(i) NORMAL LANDING CASE:

-In this case, aircraft should come to stop within 60% of landing distance runway length.

(ii) NORMAL TAKE OFF CASE:

-In this case minimum clearway width should be 150m and must be free from obstruction.

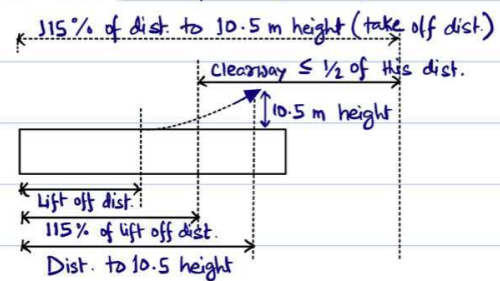
-In this case, basic runway length may consider clearway or stopway or both.

-Stopway is the area beyond the runway.

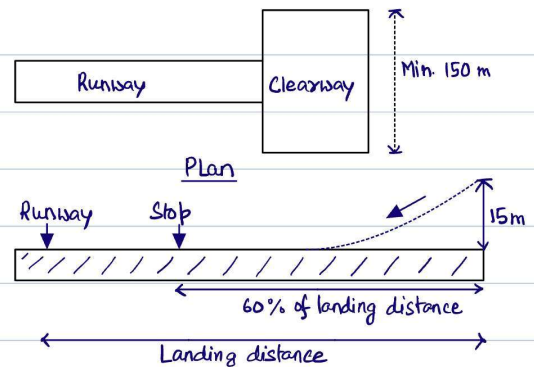
-It is mainly used to decelerate the aircraft and bring it to stop during aborted take off.

-The strength of stopway should be sufficient to carry weight of aircraft without standard damage to aircraft.

-If the engine has failed at speed less than the designated engine failure speed, aircraft is decelerated with the use of stopway.

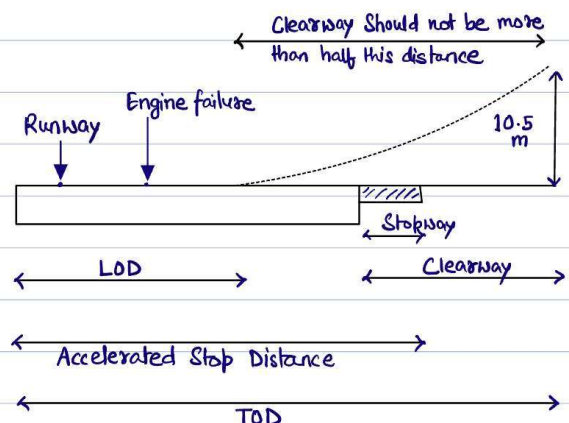


Longitudinal Section



{ This diagram will be above point j }

iii) Engine failure



- In this case, basic runway length may consider clearway or stopway or both.

- Stopway is the area beyond the runway.

- It is mainly used to decelerate the aircraft and bring it to stop during aborted take off.

- The strength of stopway should be sufficient to carry weight of aircraft without structural damage to aircraft.

- If the engine has failed at speed less than the designated engine failure speed, aircraft is decelerated with the use of stopway.

CORRECTION ON BASIC RUNWAY LENGTH

(A) CORRECTION FOR ELEVATION

- As the elevation increases air density reduces.

- Lift reduce on the wing of aircraft and aircraft requires greater ground speed.

- To achieve greater ground speed, longer length of runway is required.

(BRL)

- Hence basic runway length should increase at rate of 7% per 300m rise in elevation from MSL.

(b) CORRECTION FOR TEMPERATURE

- As airport temperature rise, same effect as the rise in elevation of runway is observed.

- Here airport reference temperature (ART) = $T_1 + \frac{1}{3}(T_2 - T_1)$.

T_1 = Monthly mean of average daily temperature of the hottest month of year ($^{\circ}\text{C}$).

T_2 = Monthly mean of maximum daily temperature for the same month ($^{\circ}\text{C}$).

- compute the standard temperature at given elevation (STE)

- Here STE = Temperature at MSL $\pm$ rate of change of temperature $\times$ elevation

Rate of change of temperature	Height
$-6.5^{\circ}\text{C}/\text{km}$	$\leq 11\text{km}$
Constant at -56.5°C $+1^{\circ}\text{C}/\text{km}$	11-20 km 20-32 km

- Compute increase in ART above STE = ART - STE

- Increase basic runway length by 1% for 1°C rise in ART above STE.

- This correction is applied after BRL is been corrected for elevation.

Check: Combination of correction due to elevation and temperature must not exceed 35%.



(iii) CORRECTION FOR GRADIENT

- In steeper gradient, to attain the desired ground speed longer length of runway is required.

- After elevation and temperature correction are applied, BRL must be increased by rate of 20% for every 1% effective gradient.

Note: Effective gradient is defined as maximum difference in elevation between highest and lowest point on

runway divided by total length of runway.



Q Length of runway under standard conditions is 1620 m. The airport site has an elevation of 230 m. If the required temperature is 32.94°C and runway is to be constructed with effective gradient of 0.2%. Then determine the corrected runway length.

Solution - (i)

correction for elevation = $7/100 \times 1/300$

$$\times 230 \times 1620 = 86.94 \text{ m.}$$

corrected runway length =

$$1620 + 86.94 = 1706.94 \text{ m.}$$



$$(ii) STE = 15 - 0.0065 \times 230 = 13.5^\circ C$$

$$\text{Increase of ART Over STE} = 32.94 - 13.5 = 19.44^\circ C$$

correction for temperature =

$$1706.94 \times 19.44/100 = 331.82 \text{ m.}$$

$$\text{Correction for length} = 1706.94 + 331.82 = 2038.76 \text{ m}$$

check, combined correction % =

$$\frac{2038.78 - 1620}{1620} \times 100 = 25.85\% < 35\%$$

(iii) Correction for gradient =

$$\frac{20}{100} \times \frac{0.2}{1} \times 2038.76 = 81.54 \text{ m.}$$

$$\text{corrected length} = 2038.76 + 81.54 = 2120.22 \text{ m.}$$



Q. The data of a hottest month of year is analysed as: mean of maximum daily temperature is 43.72, mean of average daily temperature 20.32°C, find ART.

$$\text{Solution} - ART = T_a + (T_m - T_a)/3 = 20.32 + (43.72 - 20.32)/3 = 28.12^\circ C.$$

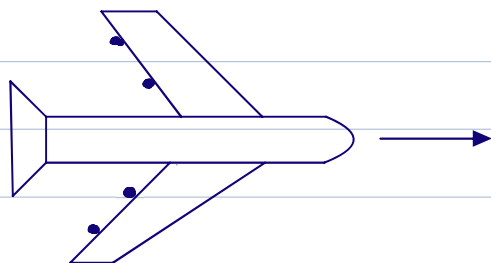
- Apart from runway length several other parameters also forms the

part of geometric design of runway.

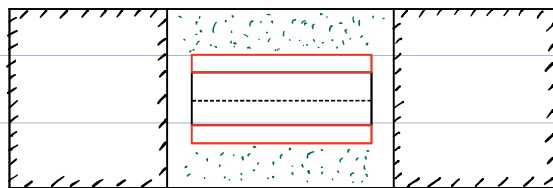
(a) RUNWAY WIDTH



- ICAO recommends the runway width in range of 10-45 m.
- It is on the basis of fact that outer engine should not damage by dust of the shoulders of runway.



(b) width and Length of Safety area



- width of safety area is runway plus shoulder on either side of runway plus the area that is cleared graded and drained.



- It is used for emergency during aircraft operations.

- For non-instrument runway width of safety area is minimum 150 m for

A, B, C type of aircraft and 78 m for D, E type.



- For instrumental runway minimum width is of 300 m.

- length of safety area is 60 m beyond runway at both end.

Note: Airport classification A to E is on the basis of runway length as follows -

Airport type A : Having longest runway

Airport type E : Having shortest runway

Airport type	Basic Runway length (m)		Runway width	Max. Transverse Gradient (%)
	Maximum	Minimum		
A	—	2100	45	1.5
B	2099	1500	45	1.5
C	1499	900	30	1.5
D	899	750	22.5	2
E	749	600	18	2



(c) LONGITUDINAL GRADIENT



- More is the longitudinal gradient more is the requirement of runway length.

For A, B, C type of airport : 1.5% (max)

D, E type of airport : 2% (max)

(d) RATE OF CHANGE OF LONGITUDINAL GRADIENT

For A, B type of airport : 0.1% per 30m length.

C type of airport : 0.2% per 30m length

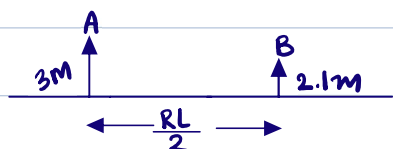
D, E type of airport : 0.4% per 30m length

(e) SIGHT DISTANCE



- for A, B, C type of airport any two points which are "3m" above the surface of runway should be mutually visible from a distance equal to half of runway length.

- for D, E type of airport any point 3m above runway and 2.1m above runway, should be mutually visible from distance equal to half of runway length.



AIRPORT CAPACITY

- Number of movements of aircraft which an aircraft can handle safely within unit time (hr) is termed as "AIRPORT CAPACITY".

(Here movement means landing or take off operation).



- Airport operating capacity depends upon -

(a) Number of runway, configuration of runway and taxiway.

(b) Weather Conditions

(c) Obstruction nearby airport

(d) Apron / parking

(e) Navigation aids.

Note - Same factors also regulates the capacity of runway.

GATE CAPACITY



- It is defined as a parking space, adjacent to the terminal building for loading and unloading of passengers, luggage or cargo, mail.

- The capacity of gate depends on -

(a) Type of aircraft.

(b) Number of passengers, baggage, mail.

(c) Type of flight (originating or through)

- Gate capacity is given by

$$GC = \text{Min} \left(\frac{G_i}{T_i \cdot M_i} \right)$$

G_i = Numbers of gates that can accommodate a particular type of aircraft.

T_i = average gate occupancy time of an aircraft

M_i = fraction of aircraft type requiring service.

Total requirement of future gates is given by =

$$\left[\frac{(\text{Present} - 2) \times \text{future passenger}}{\text{gates} \quad \text{Present passenger}} \right] + 2$$
$$= \left[\frac{(4 \times 5 - 2) \times 3}{1} \right] + 2 = 18 \times 3 + 2$$
$$= 56$$

Q Find the capacity of 15 gates that serve three class of aircraft

Aircraft Class	% Minimum	Average Occupation time (min)
A	40	25
B	25	45
C	35	60

SOLUTION - Assuming each gate is available for all aircraft
Capacity of all gates =

$$15 \times \frac{1}{0.4 \times 25 + 0.25 \times 45 + 0.35 \times 60}$$

$$= 0.355 \text{ aircraft/Min} = 21.3$$

$$= 21 \text{ aircraft/hour.}$$

TAXIWAY DESIGN

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

Taxiway should be so arranged that landed aircraft, during taxiing towards apron should not interfere with aircraft taxiing for take off.

- Route of taxiway should be shortest from apron to runway
- Taxiway should be located at various points so that landing aircraft leaves the runway as early as possible.

- There should be no intersection between runway and taxiway.

Geometric design of taxiway

- Since the speed of aircraft at taxiway is much lower than speed at runway the design standards of taxiway are much lower than runway.



(a) Length of taxiway: NO specification, but it should as short as possible.

(b) Width of taxiway: No specification, but is in range of (7.5-22.5)m.

(c) Longitudinal gradient: for A, B, C

type of airport $\nless 1.5\%$
for C, D, E type of airport $\nless 3\%$

(d) Rate of change of longitudinal gradient:

for A, B, C type of airport: 1% per 30m.
for D, E type of airport: 1.2% per 30m.

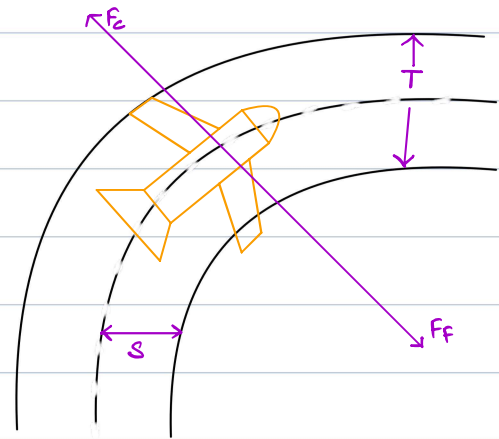
(e) Transverse gradient: for A, B $\nless 15\%$

(f) Sight distance: for A, B, C type of airport, surface of taxiway should be visible from 2.1 m height at 250 m distance.



(g) Turning radius

- for changing the direction of taxiway horizontal curve is required. Radius R is given by,



$$R = \frac{V^2}{125f}$$

— A



R = Radius (m)

V = Speed (kmph) $f = 0.13$

f = Lateral transverse friction

- for large subsonic aircraft minimum R = 120m.

Supersonic aircraft Minimum R = 180m

- Radius of taxiway should also be provided such that the distance of the main gear extreme tyre is not less than 6 m from the pavement edge and can be computed as

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

— (B)



W = wheel base of aircraft (m)

T = Width of taxiway (m)

S = Distance between mid point

Of the main gear and edge of taxiway.



- Radius of taxiway provided is greater of A, B and min specified value.

Q. A taxiway is to be designed for operating aircraft having following characteristics

Wheel base = 18 m

Tread of main landing gear = 6.62 m

Turning speed = 40 kmph

$$f = 0.13$$

$$T = 22.5$$

Solution — $R = \frac{V^2}{125f} = \frac{(40)^2}{125 \times 0.13} = 98.46 \text{ m} \quad \text{--- (A)}$

$$\text{also } R = \frac{0.388 W^2}{\frac{T}{2} - S} = \frac{0.388 \times 18^2}{\frac{22.5}{2} - (6 + \frac{6.62}{2})}$$

$$R = 64.8 \text{ m} \quad \text{--- (B)}$$



$$\text{also min } R = 120 \text{ m} \quad \text{--- (C)}$$

$$R = \text{Max}(98.46 \text{ m}, 64.8 \text{ m}, 120 \text{ m}) = 120 \text{ m}.$$

EXIT TAXIWAY



- At busy airport, taxiway should be located at various points along the runway, so that aircraft leaves the runway as soon as possible.

- These taxings are termed as EXIT TAXIWAY.

- Location of the exist taxiway depends on following factors.

(a) Topographic features: high altitude or deep valley or obstruction reduces the visibility which may affect the landing speed and location of exit taxiway.



(b) Weather Condition: Wind, temperature, fog, etc. affect the landing speed hence location of exit taxiway.

(c) Number of exit taxiway: If there are only two exit taxiway then they should be at end of the runway and if there are more two, then they are distributed along the runway length.

(d) Exit Speed: Location of exit taxiway should be such that where aircraft have sufficient reduced speed to take the safe turn.



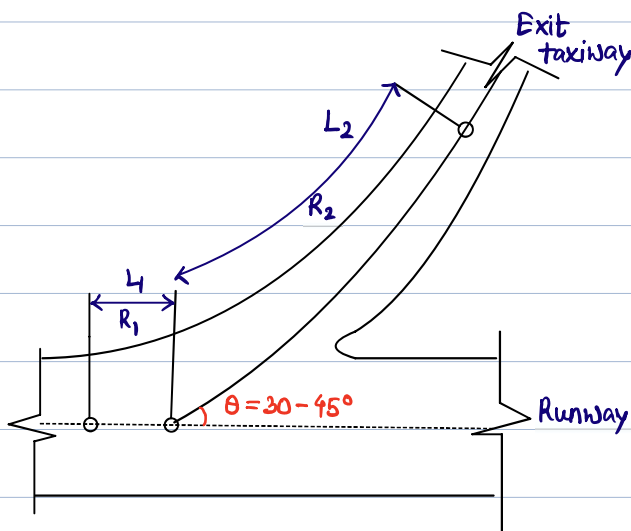
Design of exist taxiway connecting runway



- Here most significant factor is exit speed that governs the radius.
- Slightly widen entrance which gradually taper to the normal width of taxiway is preferred.
- Total angle of turn of $36-45^\circ$ can be negotiated Satisfactory.
- Length of the larger radius (R_1) can be computed empirically as

$$L_1 = \frac{(0.28V)^3}{CR_2}$$

$C = \text{coefficient} = 0.39$



SEPERATION CLEARANCE

- The distance between parallel taxiway for safe movement of aircraft is termed as SEPERATION CLEARANCE.



It depends on-

- (a) Navigation aids
- (b) Wing span of aircraft
- (c) Type of aircraft

APRON

- It is a paved area for parking of aircraft, loading and uploading the passenger and cargo.

- This area is near to the terminal.

- It should have adequated gradient for drainage. ($\geq 1\%$)



- Size of apron depends on following factors.

(a) AIRCRAFT PARKING SYSTEM

(i) Frontal System : It is very simple and economical and it used for small airport.

TERMINAL BUILDING

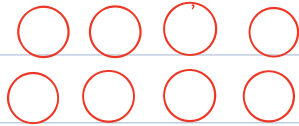


(ii) OPEN AREA SYSTEM

- Here aircraft are parked in row.

TERMINAL BUILDING

- Passengers have to walk or vehicles



are required in this case.

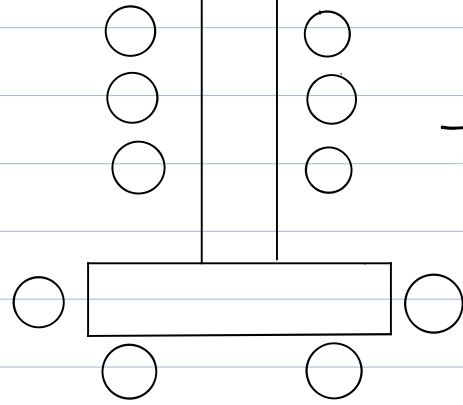
- Passengers are exposed to weather and hot blast of jet aircraft.



(iii) Finger System

- It provides protection to the passenger from weather, noise, jet blast.

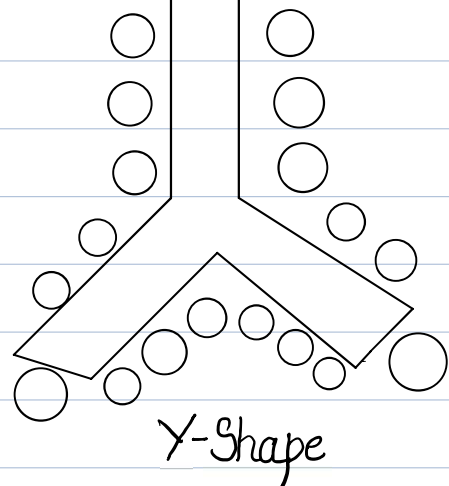
TERMINAL BUILDING



T-Shape

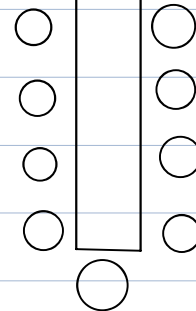


TERMINAL BUILDING



Y-Shape

TERMINAL BUILDING



Straight



- future expansion is easier.
- Aircraft remains close to the terminal building.

(iv) Satellite System



- Satellites are small building located on apron.

- Aircraft are parked near the satellite building and this connect to the terminal building by tunnels.

- It has high constructional cost, but it requires less turning.

each aircraft remain in a gate position.



- This time is also known as "RAMP Time" which varies from few mins to an hour depending upon the type of aircraft.

- Number of gate positions is given by

$$\text{Gate position number} = \frac{\text{Capacity of runway}}{60 \times 2} \times \frac{\text{Average gate occupancy time.}}{}$$

(b) SIZE OF LOADING AREA



- Size of loading area directly governs the size of apron.

- It is also known as GATE POSITION.

- Size of loading area/gate position depends upon the type of aircraft, turning radius etc.

(c) NUMBER OF GATE POSITION

- Numbers of gate positions depends upon the peak hourly aircraft movement and time during which

VISUAL AIDS AND DRAINAGE SYSTEM



- Pilot needs visual aids for perspective view of runway during landing and take off operation.

- Runway edges and runway central line is amongst the things which should be clearly visible to the pilot.

- In day time visibility is enhanced by marking the line and numbering having maximum contrast with the surroundings under all conditions.

-In night time, adequate lighting is provided for same.



(A) AIRPORT MARKING

-Runway marking consist the marking of central line, edge strip touch down zone/landing zone.

-All marking is done in yellow colour paint having width of 0.9 m.

-Taxiway marking is done in yellow colour paint having width of 0.15m.

-Taxiway marking should start at min 60m before the exit taxiway.

-Runway shoulder marking is done in yellow paint and has diagonal line having width of 0.9m.



-Taxiway shoulder and apron holding shoulder are marked perpendicularly.

-Blast pad at the end of runway is marked with yellow paint having chevron pattern.

-Apron marking is done by yellow paint.

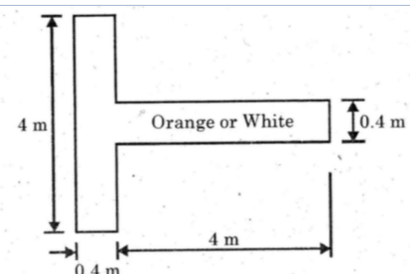
-Since fuel is like to spill over, paint should be fuel resistant.

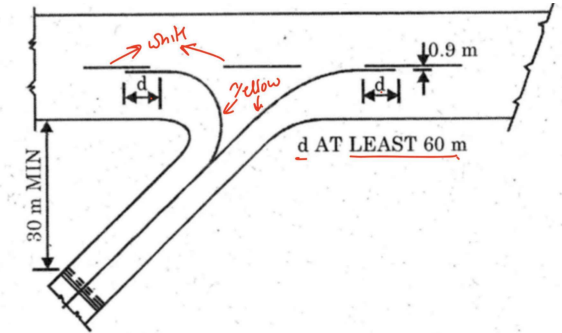
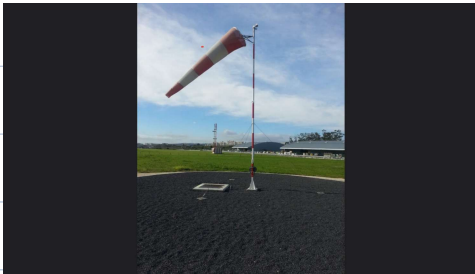
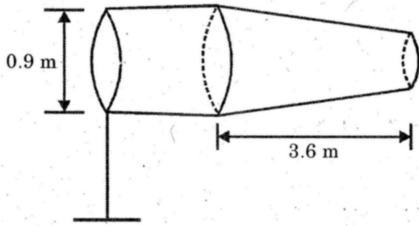
-Some guide lines are painted on apron to help pilot in operating the aircraft on the apron.



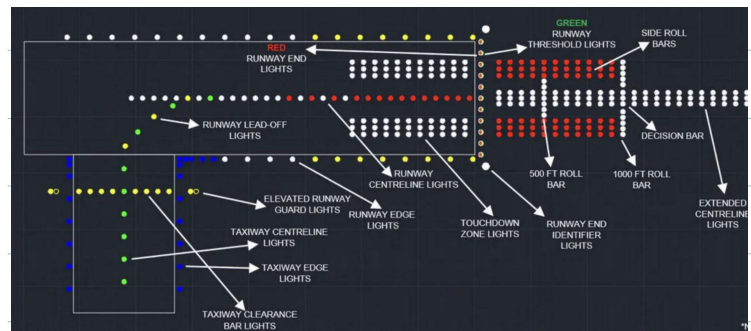
-Wind direction indicator consist of wind cone that must be placed away from building inside a circle with diameter of 30m (internal) and panel width of 0.9m-2.4m.

-It should have colour which is in contrast with background.





ESENOTES.COM





sized for all civil airports.

-Threshold lighting is provided 60 m ahead of runway, where a pilot makes decisions whether to land or not.



-Taxiway light should be clearly identified and different with runway to avoid confusion.

-All taxiway side lights are blue coloured and centre lights are green.

-Exit taxiway should be lighted 360m-450 m ahead of turn off.

-Runway edge lights are spaced 60 m and centre lights are spaced at 12.5-15 m and are usually white

-Apron and hanger area should have flood light having at least 12 m height above pavement



-Landing direction indicator is properly lighted for night operation

Note - Apart from visibility aids, Air traffic control aids also helps in proper operation.

-Landing direction indicator is in form of T-Shape and is at the centre of segmented circle.



-It's purpose is to indicate the pilot direction of active runway.

AIRPORT LIGHTING



-In the night duration, airport lighting provides better visibility to landing and taking off and taxing operation.

-Colour and general pattern of lights used in airports are standard-

- Air traffic control aids are further of two types -



(a) VFR (VISUAL FLIGHT RULES)

(b) IFR (INSTRUMENTAL FLIGHT RULES)

- VFR prevails when the weather condition is good and uplift can manage with visual aids during operation.

- IFR prevails when the visibility is inadequate during night time or due to bad weather.

AIRPORT DRAINAGE

- A proper drainage is essential for safety of aircraft and long life of pavement.

- A drainage system in airfield normally serves following function -

(a) Removal of surface run off.

(b) Interception and diversion of surface and ground water flow originating from lands adjacent to the airfield area.



(c) Lowering of sub-surface water level in airfield.

- The drainage system of airfield consists of -

(a) SURFACE DRAINAGE

(b) SUB-

SURFACE DRAINAGE



HELIPORT

- Helipads/Heliports is the designated area where facilities are provided for take off and landing of helicopters.

- Helicopters have following advantages over aircraft:-

(a) It can lift off ground in a nearly vertical direction.

(b) It can be used in winters and in rainy seasons.



(c) It is suitable short haul distances.

(d) It can be used as ambulance and for military purposes.

- following points are considered for selection of heliport location -

(a) It should be located in close proximity to traffic generating areas.

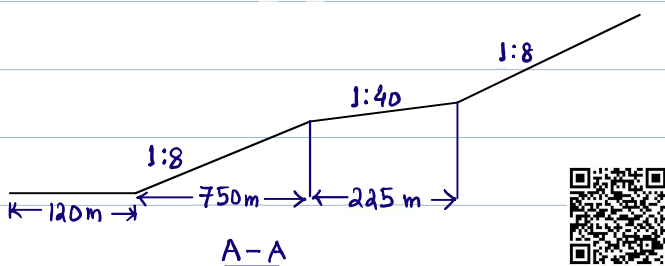
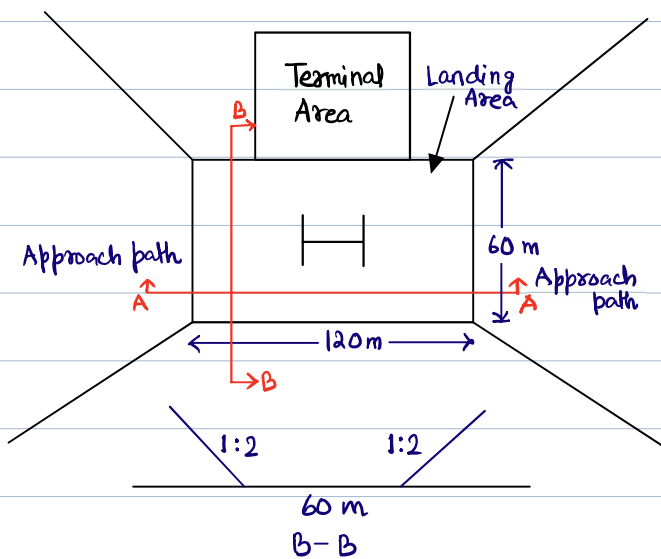
(b) It should have a convenient areas by ground transportation i.e roadway or railway.



(c) Site should be least objectionable for noise.

(d) As per ICAO recommendation, the obstruction clearance line should have slope of 1:8 upto 750m, beyond this 1:40 upto 225m and then followed by slope of 1:8.

(e) In transverse direction the slope of obstruction clearance line is 1:2.



-Size of landing area as per helicopter type is as follows-

Type of helicopter	Size of landing area
(a) Single Engined	
(i) 2700 Kg wt.	22.5m x 22.5 m
(ii) 6800 Kg wt.	30 m x 30 m
(b) Multi Engined	60m x 120m

- ICAO recommends the minimum width which is equal to twice the diameter of main rotor of larger helicopter expected to use the helicopter.



TUNNEL ENGINEERING



- A tunnel is an engineering structure, artificial gallery or passage constructed

beneath the ground under the bed of stream or hill or mountain.

- It provides passage for transporting passengers, freight, water, sewage or gas, etc.

- Tunnels offers following advantages-

(a) It is economical

(b) It avoids dangerous cut nearby to the structure.

(c) It can be used during warfare.

Classification of tunnels



- classification of tunnels can be done as follows-

(a) ON THE BASIS OF TRAFFIC



- RAILWAY TUNNEL
- HIGHWAY TUNNEL
- PEDESTRAIN TUNNEL

(b) ON THE BASIS OF CONVEYANCE

- WATER SUPPLY TUNNEL
- SEWER TUNNEL
- POWER TUNNEL

(c) ON THE BASIS OF QUALITY OF MATERIAL

- HARD ROCK TUNNEL
- LOOSE SAND / QUICK SAND TUNNEL
- OPEN CUT TUNNEL

(d) ON THE BASIS OF POSITION / ASSIGNMENT

- SADDLE / BASE TUNNEL
- SPIRAL TUNNEL
- OFF SPUR TUNNEL



SHAPE OF TUNNELS

- The shape of the sectional profile of a tunnel should be such that the lining is able to resist the pressure exerted by the unsupported walls of tunnel excavation.

- commonly adopted shapes are -

(a) CIRCULAR (best for resisting external loads)

(b) POLY CENTRIC

(c) HORSE SHOE SHAPED (generally used for traffic operation)

(d) EGG SHAPED (for sewers)

(e) ELLIPTICAL

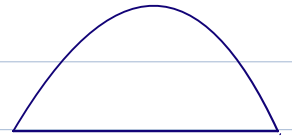
(f) RECTANGULAR / SQUARE



SHAFTS

- These are vertical walls

or passage sunk along the centre line of



tunnel, to permit the tunnel excavation

- It also provides openings for removal of the excavated materials

- It also provides adequate ventilation during construction of tunnel.

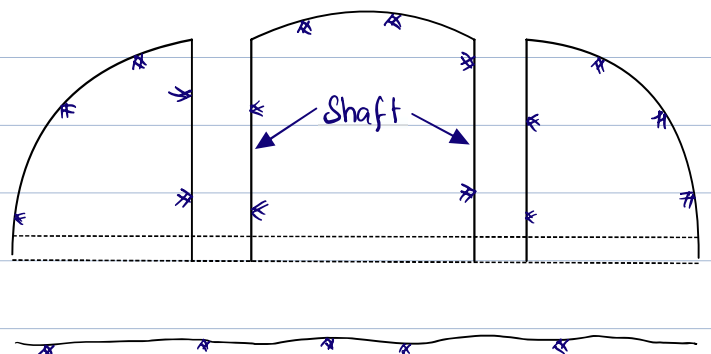
- Size of shaft is governed by the following factors:-



(a) Amount of muck to be hoisted.

(b) Hoisting system to be adopted.

(c) Size of muck car.



(d) No. of workmen required.

(e) Type of court equipment to be used.

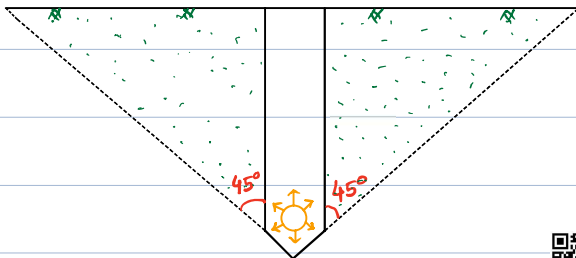
(f) Size of pipe and wiring required.

DRILLING OF SHAFT

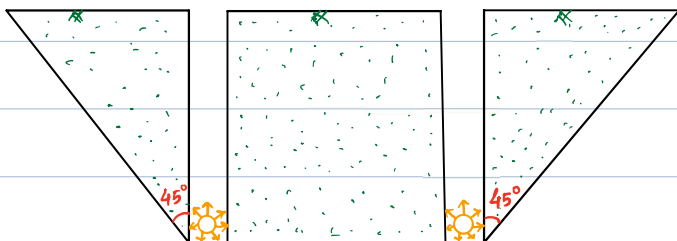


- Before excavating rocks, they are loosened by drilling holes, filling them with explosive and firing them.

- The drill hole normal to the face when exploded with proper charge will break out the rock in following pattern.



- If two similar holes are kept side by side and fired together they will break the ground in the trapezoidal pattern.



DRILLING EQUIPMENTS

- The type of drilling equipments depends upon the nature of the terrain, the kind of rock, the depth and size of holes, etc.

(A) PERCUSSION DRILLS

- This drill breaks the rock by impact from the repeated blows.

(B) ABRASION DRILLS

- This drill grind rock into small particles through abrasive effect of bit that rotates in holes.

- It is used to drill holes upto 100m depth.

(C) FUSION PIERCING

- This drill produces burning mixture of oxygen and flux bearing fuel such as kerosene at the end the blow pipe, which increases its effectiveness

DRIVING TUNNELS

-For driving tunnels in rocks the following operations are adopted -

- (a) Setting up and drilling
- (b) Loading holes and shooting the explosives.
- (c) Ventilation and removing dust of explosion.
- (d) Loading and hauling muck
- (f) Placing the reinforcement steel.
- (g) Concrete lining.

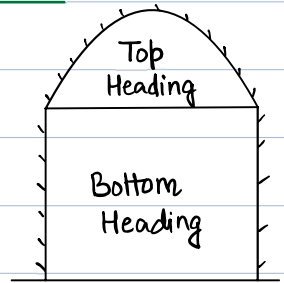
-Tunnelling in rocks can be done by any of following -

(a) FULL FACE MTD

- In this mtd whole section of the tunnel is attacked at same time.
- It is suitable for tunnels of small cross section for short spans (3m)
- Here tunneling is continuous and mucking track could be laid progressively along with the tunnel.
- It require heavy machinery.
- It is not suitable for unstable rocks.

(b) HEADING AND BENCH MTD

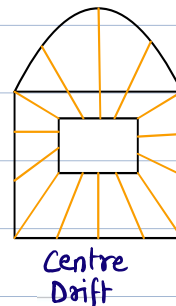
-This mtd involves the driving of the top portion in advance of the bottom portion.



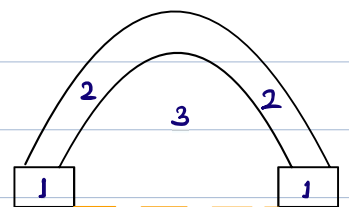
- It is used when tunnel section is very large and quality of bed rock is not very satisfactory or unstable.
- Simultaneous drilling and mucking is possible in this case.
- Here power requirement is less than full face mtd.

(c) DRIFT MTD

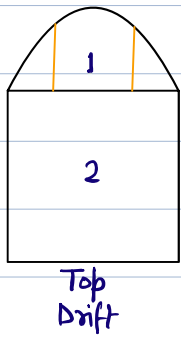
- In this mtd. tunneling is carried out first in smaller section of the proposed tunnel and then it is widened.
- It helps in ventilation of tunnel.
- Drift may be done as -
 - Centre drift
 - Side drift
 - Top drift
 - Bottom drift



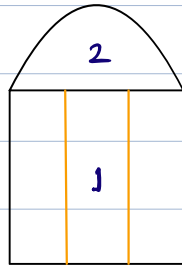
Centre Drift



Side drift



Top Drift



Bottom Drift

DRIVING TUNNELS IN SOFT GROUND

- The material which can be excavated with tools like picks, shovel and no heavy equipment are termed as soft ground.

- It can be done by any of following mtd -

- Fore Poling mtd
- Needle Beam mtd
- Belgian mtd
- English mtd
- Army mtd
- German mtd

These mtd require use of timber

- Linear plate mtd
- Shield mtd
- Compressed air tunneling

These mtd do not require timber.

Previous Year Questions

Runway Planning

Q. The radius of horizontal circular curve is 480m and design speed therein 70 Kmph. What will be the equilibrium superelevation for the pressures on the inner and the outer wheels to be equal?

(a) 5%

(b) 6%

(c) 7%

(d) 8%

SOLUTION - (d) $e = \frac{v^2}{127R}$

$$e = \frac{70^2}{127 \times 480} = 8\%$$

IES - 2015

Q. Wind-rose diagram is useful in deciding on the orientation of:

(a) Taxiway

(b) Hanger

(c) Apron

(d) Runway

SOLUTION: (d) In wind rose diagram, direction, intensity, duration of wind data are represented. This diagram is useful in deciding the orientation of runway for take off and landing operations.

Q. For safe landing and take off, the following factors need to be carefully considered:

1. Cross-wind
2. Runway grade
3. Runway width and side clearance
4. Obstructions

(a) 1, 2 and 3 only

(b) 1, 2, 3 and 4.

(c) 1, 3 and 4 only

(d) 2, 3 and 4 only

SOLUTION: For safe landing and take off operations cross wind component, width of runway and obstructions on runway plays important role.

Also, abrupt change of longitudinal gradient restricts the height distance and may also cause premature lift off of the aircraft during the taking off operation.

Q. Which one of the following instances of performance of aircraft is not considered for determining basic runway length?

(a) Normal landing case

(b) Normal take-off case

(c) Engine failure case

(d) Emergency landing case

SOLUTION: (d) Basic runway length is determined by 3 cases:

(i) Normal landing case

(ii) Normal take off case

(iii) Engine failure case

Q. The runway length for an airport located at 460m above MSL, corrected for elevation, is 3670m. The monthly means of maximum and mean daily temperatures for the hottest month of the year are 27°C and 18°C, respectively. What will be the final corrected length of the runway with correction incorporated also due to temperature effects?

(a) 4500m

(b) 4000m

(c) 3750m

(d) 3400m

SOLUTION: Standard temp at elevation = $15^{\circ}\text{C} - 0.0065 \times 460 = 12.02^{\circ}\text{C}$

$$\text{Airport reference temp} = T_a + \left(\frac{T_m - T_a}{3} \right)$$

$$= 18 + \left(\frac{27 - 18}{3} \right) = 21$$

$$\text{Correction for temperature} = \frac{3670}{100} (21 - 12.02)$$

$$= 329.933$$

$$\text{Corrected length} = 3670 + 329.933 = 4000 \text{ m}$$

SOLUTION: Basic runway length has to be corrected for elevation, temperature and gradient.

ICAO recommends that the basic runway length should be increased at the rate of 7% per 300 m rise in elevation above the mean sea level.

IES 2007

Q. As the elevation increases, the runway length has to be changed at what rate?

(a) Decreased @ 5% per 300 m rise in elevation above M.S.L.

(b) Increased @ 7% per 300 m rise in elevation above M.S.L.

(c) Decreased @ 9% per 300 m rise in elevation above M.S.L.

(d) Increased @ 15% per 300 m rise in elevation above M.S.L.

Q. The lowest height above the runway where the pilots make the decision to continue the landing manoeuvre or to cut it short is called the

(a) Runway height

(b) Decision height

(c) Threshold height

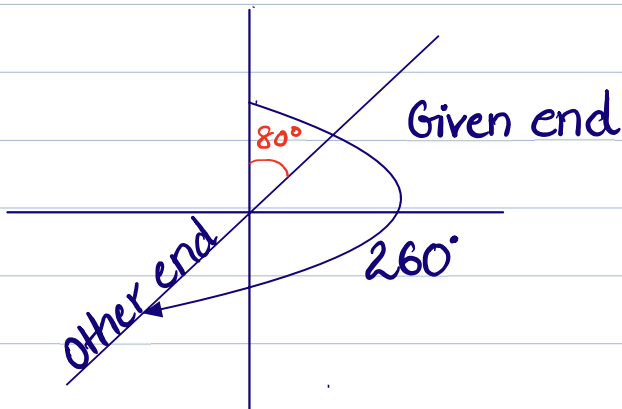
(d) Runway visual range

SOLUTION: (b) Decision height

Q. The magnetic azimuth of one end of a runway is 80° measured clockwise from the magnetic north. The other end of the runway will be numbered as

- (a) 16
- (b) 24
- (c) 26
- (d) 8

SOLUTION : (c)



As magnetic azimuth of other end is 260° , therefore its number should be 26.

Q. Match List-1 (unit) with List-II (Purpose) and select the correct answer using the code given below the lists :

List-1	List-2
A. Width and Length of airport.	1. Basic runway length.
B. Engine failure case.	2. Runway geometric design.
C. Location of exist taxiway.	3. Airport drainage
D. Grading of airport size.	4. Runway capacity.

Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	3	1	4	2
(c)	2	1	4	3
(d)	3	4	1	2

SOLUTION: (c) For design of runway width and length of safety area is considered. For determination of basic runway length engine failure case is considered.

Factors affecting runway capacity is number, location and design of exist taxiways.

Entire airport area is properly

graded to enable the quick drainage of storm water.

AIRPORT CAPACITY

Q. In an airport, if 4 groups of gates each located well-separated are considered for traffic and the future-to-present traffic ratio is 3, then the total required of future gates will be

- (a) 32 (b) 36
(c) 44 (d) 68

SOLUTION: (d)

As per Stafford,
future gates =

$$\left[\frac{(\text{present gates} - 2) \times \text{future passenger}}{\text{present passenger}} \right] + 2$$

$$= [(4 \times 5) - 2] \times 3 + 2$$
$$= 56$$

As options are not matching it is better to opt more gates.

Q. Which one of the following gives the number of gate position in an airport?

(a) $\frac{\text{Capacity of runway}}{2} \times \text{average occupancy time}$

(b) $\frac{\text{Capacity of apron}}{60 \times 2} \times \text{number of aircraft movements}$

(c) $\frac{\text{Capacity of taxiway}}{60 \times 2} \times \text{average gate occupancy time}$

(d) $\frac{\text{Capacity of holding apron}}{2} \times \text{average gate occupancy time.}$

SOLUTION : (a) Number of gate positions depends upon the peak hourly aircraft movements and the time during which each aircraft remains in a gate position.

It can be found out using following relationship

$$\therefore \text{Number of gates} = \frac{\text{Capacity of runway}}{60 \times 2} \times \text{average gate occupancy time}$$

Q. If M_i = Proportion of i th type of aircraft in the mix, T_i = 'Gate occupancy time' of the i th type of aircraft. G = Number of gate (considering that all the available gates can be using by all aircrafts)

Which one of the following equations gives the ultimate gate capacity C ?

$$(a) C = \frac{\sum_{i=1}^n G \times M_i}{\sum_{i=1}^n T_i}$$

$$(b) C = \frac{G \times 60}{\sum_{i=1}^n M_i \times T_i}$$

$$(c) C = \sum_{i=1}^n \left(\frac{M_i}{G} \right) \times T_i$$

$$(d) C = \frac{G}{\sum_{i=1}^n M_i \times T_i}$$

SOLUTION : (d) $C = \frac{G}{\sum_{i=1}^n M_i \times T_i}$

TAXIWAY DESIGNS

Q. Castor angle is defined as the angle

(a) Formed by the Longitudinal axis of the aircraft and the direction of movement of the nose gear.

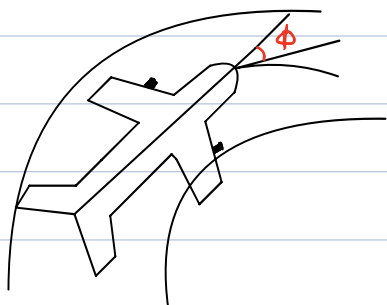
(b) Between the direction of wind and the longitudinal axis of the runway.

(c) Between the true speed of the aircraft and the crosswind component.

(d) Between the horizontal and the fuselage axis.

SOLUTION : (a) Castor angle is the angle formed between the tangent to the centre line and the longitudinal axis of the aircraft.

ϕ = Castor angle



SOLUTION : (d) The design of taxiways system is governed by the volume of aircraft movement, the runway configuration and the location of the terminal building and other ground facilities like hangar location. Exit taxiways are provided at suitable locations along the length of runway to clear the runways of the landed aircraft.

Q. Match List-1 (Component) with List-2 (Design Feature) and select the correct answer using the code given below the lists

Q. Which of the following factors are to be taken into consideration while designing the taxiway system?

1. Volume of air traffic
2. Runway configuration
3. Location of hangars

Select the correct answer using the codes given below:

- (a) 1, 2 and 3.
- (b) 2 and 3
- (c) 1 and 4
- (d) 1, 2, 3 and 4

List 1	List 2
A. Taxiways	1. Large span structures
B. Control tower	2. Visibility all round and sound proof.
C. Hangar	3. Turning radius
D. Apron	4. Waiting capacity for aircraft.

Codes :

	A	B	C	D
(a)	1	4	3	2
(b)	3	2	1	4
(c)	1	2	3	4
(d)	3	4	1	3

SOLUTION : (b) The main function of taxiway is to provide access to the aircrafts from the runways to the loading apron or service hangar and back. Hangar provides an enclosure for servicing and doing repairs of aircrafts. Apron is a paved area for parking of aircrafts and loading and unloading of passengers and cargo.

Control tower is nerve centre of an airport. In order to control tower is so located as to command a clear view of the airfield.

Q. What shall be the radius of an exit taxiway with design exit speed of 90 kmph and coefficient of friction 0.13?

- (a) 550 m (b) 500 m
(c) 475 m (d) 449 m

SOLUTION : (b) $R = \frac{V^2}{125f}$

$$R = \frac{90^2}{125 \times 0.13}$$

$$R = 498.46 \approx 500 \text{ m}$$

Q. Consider the following data for designing a taxiway for operating Boeing 707-320 aeroplane :

Wheel base = 17.70 m

Tread of main landing gear = 6.62 m

Turning speed = 40 km/hr

Coefficient of friction between tyres and pavement surface = 0.13
The turning radius of the taxiway will be

- (a) 98.5 m (b) 94.5 m
(c) 89.5 m (d) 86.5 m

SOLUTION : (a) Turning radius (R) of taxiway

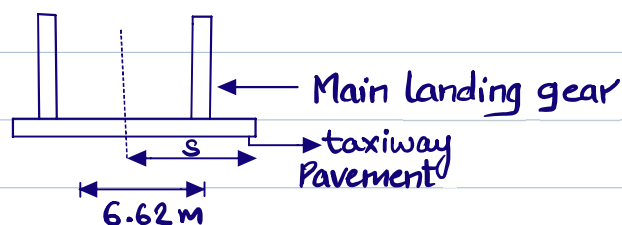
$$(i) R = \frac{V^2}{125f} = \frac{40^2}{125 \times 0.13} = 98.5 \text{ m}$$

(ii) As per Horenj eff. equation

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

'W' is wheel base = 17.7 m

'T' is width of taxiway = 25 m (assuming)



$$\therefore S = \frac{Tread}{2} + 6$$

[6m is the minimum edge distance]

$$= \frac{6.62}{2} + 6 = 9.31 \text{ m}$$

$$\therefore R = \frac{0.388 \times 17.7^2}{\frac{25}{2} - 9.31} = 38.103 \text{ m}$$

Hence, maximum of these two will be considered as turning radius of taxiway.

$$\therefore R = 98.5 \text{ m}$$

Q. The Longitudinal section of a runway provides the following data:

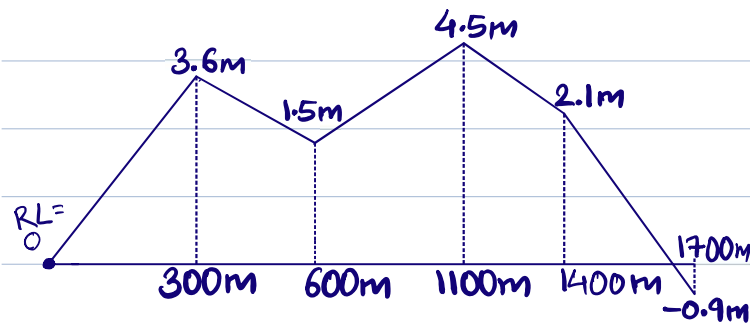
End-to-end runway (m)	Gradient
0 to 300	+1.2
300 to 600	-0.7
600 to 1100	+0.6
1100 to 1400	-0.8
1400 to 1700	-1.0

The effective gradient of the runway (in % round off to two decimal places) is

SOLUTION : (0.32)

Assuming RL of start of runway as datum (i.e. RL = 0m)

Chainage (m)	0-300	300-600	600-1100	1100-1400	1400-1700
Gradient	+1.2%	-0.7%	+0.6%	-0.8%	-1.0%
Rise or fall	$\frac{+1.2}{100} \times 300 = +3.6 \text{ m}$	-2.1m	+3m	-2.4m	-3.0m
Cummulative	+3.6m	+1.5m	+4.5m	+2.1m	-0.9m



$$\text{Effective gradient} = \frac{\text{Maximum difference in reduced level}}{\text{Total runway length}}$$

$$= \left[\frac{4.5 - (-0.9)}{1700} \times 100 \right] \%$$

$$= 0.3176\% \approx 0.32\%$$

Q. For the hottest month of the year at the proposed airport site. The monthly mean of the average daily temperature is 39°C. The monthly mean of the maximum daily temperature is 48°C for the same month of the year. From the given information, the calculated Airport

Reference Temperature (in °C), is

(a) 36

(b) 42

(c) 48

(d) 39

SOLUTION: (b) Airport reference temperature

$$= T_a + \frac{T_m - T_a}{3}$$

T_a = Average daily temperature

T_m = Maximum daily temperature

Given, $T_a = 39^\circ\text{C}$

$T_m = 48^\circ\text{C}$

Airport reference temperature

$$= 39 + \frac{48 - 39}{3} = 42^\circ\text{C}$$

Speed at runway exist = $V(\text{let})$

$$= V = U + at$$

$$= V = 55.55 - 1.697 \times 18$$

$$= 25 \text{ m/s}$$

Distance covered

$$= \frac{V^2 - U^2}{2a} = \frac{(25)^2 - (55.55)^2}{2 \times -1.697} = 725.09 \text{ m}$$

$$\text{Distance till stopping} = \frac{0^2 - (25)^2}{2 \times 1}$$

$$= 312.5 \text{ m}$$

Q. An aircraft approaches the threshold of a runway strip at a rate of 1.697 m/s^2 and takes 18s to exist the runway strip. If the deceleration after existing the runway is 1 m/s^2 , then the distance (in m, up to one decimal place) of the gate position from the location of exist on the runway is _____.

SOLUTION: (312.5)

Given

Speed before deceleration =

200 km/h

$$= 55.55 \text{ m/s}$$