Subject Name: **Highway Engineering**

Subject Code: **CE-6004**

Semester: **6th**

Unit IV

Airport planning, Runway & Taxiway: Airport site selection, aircraft characteristics and their effects on runway alignments, wind-rose diagrams, basic runway length and corrections, classification airports. Geometrical elements: Taxiways & Runways, pattern of runway capacity.

Introduction:

The primary modes by which transportation takes place are:

- On land
- Through water
- Through air

Transportation on land primary consists of movement by road & on rail. Transportation through water mainly consists of movement using ships, which requires docks & harbors or ports. Transportation through air consist is effected by using different types of aircraft such as airplanes & helicopters.

Airport engineering is associated with the engineering aspects of air transport. An airport is defined as a place where aircraft can takeoff & land for operating commercial services.

Characteristics of Air transport:

The positive attributes of air transport are:

- Rapidity or high speeds
- Continuous travel for long distances
- Accessibility- even to remote locations, which are normally inaccessible by other modes of transport.

The dis-advantages are:

- Need for high skill & sophisticated equipment for ensuring safety in operation.
- Difficulty in operating under un-favorable weather conditions.
- Prohibitive cost of flying.

Development of National Organizations for Civil Aviation:

The following is the sequence of development of national organizations for controlling civil aviation in India:

- International Airport authority of India (IAAI)
- Civil aviation development & National Airport Authority (NAA)
- Airport Authority of India (AAI)
- Open sky policy

Components of Airports & their functions:

- **Terminal area**
- **Landing area**

Terminal Area: this is the focal point of an airport, with several elements, each of which has its own functions. They are:

Apron: paved area parking of the aircraft for passengers to emplane & deplane & for cargo to be loaded & unloaded.

Terminal building: This building houses all facilities for the passengers, operational staff & control towers.

Motor vehicle parking & circulation area: this is meant to provide the facility of parking for the motor vehicles by which passengers arrive at end & depart from the airport.

Hangars: These are large sheds which house aircraft for servicing, fuelling & repairs. Machine shops & spare parts are necessary adjuncts for hangers.

Landing Area: This is very critical for operation of an aircraft. Landing as well as takeoff operations are performed in this area with the aid of runways & taxiways. This area includes the approach zone & clear zone & is governed by zoning laws & restrictions.

Aircraft characteristics & their influence on Airport planning & Design:

- **Type of propulsion**
- **Size of aircraft**
- **Aircraft weight & wheel configuration**
- **Tyre pressure & wheel configuration**
- **Speed of aircraft**
- **Minimum circling radius**
- **Minimum turning radius**
- **Takeoff & landing distances**
- **Range of aircraft**
- **Noise of Aircraft**
- **Fuel spilling & Jet blast**
- **Aircraft capacity**

Type of propulsion: reciprocating engine running with gasoline as fuel & a shaft connected to a propeller or a turbo jet or turbo propulsion- governs the size, weight-carrying capacity, speed, circling radius & noise created by airplane.

Size of aircraft: length of fuselage, height, wingspan, tail width, gear treads & wheel base are the important constituents that determines the size of the aircraft.

Weight of aircraft & wheel configuration: It plays an important role in deciding the runway design, range of aircraft, fuel requirements & so on.

Minimum circling radius this is the radius of the imaginary circle in space which should be free of any obstruction if the aircraft has to take a smooth & safe turn when required. It depends upon the type of aircraft & weather conditions.

Minimum turning radius: This governs the design of taxiways & helps to ascertain the positioning of aircraft on the aprons & in the hangars.

Take off & landing distances: these will govern the minimum length of runway required. These distances depend on the altitude of the airport, wind speed & direction, gradient of the runway, weight of aircraft at takeoff & landing & temperature.

Range of Aircraft: the maximum distance that an aircraft can fly without refueling is called the range, this is inversely related to pay load.

Noise of Aircraft: this is also crucial to minimize noise pollution. The noise level during takeoff is more severe than that during landing.

Aircraft capacity: this refers to the number of passengers (along with baggage & cargo) that can be accommodated.

Civil & Military aircraft: Military aircraft includes fighter planes during emergencies & wars. They are designed to travel at supersonic speeds & for heavier payloads.

Classification of Airports:
In general it is classified as:

- **Military airports: these are meant to operate military aircraft for emergencies & natural calamities at time of peace & for defence purposes during war time.**

- **Civil or Commercial aircrafts: these are meant for civil aviation for ferrying passengers & cargo/mail, both within the country & abroad.**

ICAO Classification of Airports:

The most popular classification of airports is given by the ICAO, following are the two criteria

A. **Code letter A to E are used to indicate the basic length of the runway, width of runway & the maximum longitudinal gradient (%) as given below:**
B.

Table 1:- Basic length of Runway length

Code letter	Basic length of runway (m)		Width of runway (m)	Max. Longitudinal grade (%)
	Maximum	Minimum		
A	Over 2100	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. **The numbers 1 to 7 are used to indicate the isolated wheel load & tyre pressure, as shown below:**

Table 2 Wheel load and Code of Airport

Code number	Isolated wheel load (kg)	Tyre pressure (kg.cm)
1	45000	8.5
2	34000	7
3	27000	7
4	20000	7
5	13000	6
6	7000	5
7	2000	2.5

Airport Planning:

- **Justification of the need for the airport**
- **Formulation of the layout plan based on the assessed requirements**

- **Integration of the planning with regional needs & national needs**

Steps in airport planning:

- **Estimation of traffic potential**
- **Site selection**
- **Layout plan**
- **Design of various components**
- **Preparation of working drawings**
- **Cost estimation**
- **Proposals for financing & institutional arrangements**
- **Environmental impact assessment.**

Master plan: A master plan may be made for the development of airport in the entire country on the basis of needs as well as priorities, bearing in mind national interests.

Regional planning: This aims at the formation of an effective network of airports in a zone or region & ultimately in a country, in such a way that the planning of an individual airport smoothly merges into the regional plan of other airports & the regional plan, in turn, merges into the national plan.

Improvement of an existing airport: It is essential to consider making improvements to an existing airport to cater to the needs of increased air traffic before deciding to construct an entirely new facility. For this, an appropriate traffic forecast for a reasonable design period say 20 years, is the first step.
Next, the capacity of the existing airport should be assessed in respect of the facilities such as aprons, hangars, baggage & cargo handling facilities & so on.

Site selection for an Airport:
It is an important element in airport planning. Factor affecting the site selection for an airport are:

- **Atmospheric & climatic conditions**
- **Topography**
- **Location of other airports in the vicinity**
- **Accessibility**
- **Availability of land for future needs**
- **Availability of utility services**
- **Land use pattern of the surrounding area**
- **Regional plan**
- **Soil characteristics**
- **Obstructions surrounding the site**
- **Economy of construction**

- **Purpose of the airport**

Atmospheric & climatic conditions: Visibility is affected by fog, haze & smoke, which hamper flight operations & impair its capacity.

Topography: Topographical features like ground contours, streams, trees & vegetation should be studied with the aid of topo-sheets for the area. A raised ground with good drainage & good visibility will be an ideal site.

Location of other airports in the vicinity: According to the recommendations of the ICAO, a certain minimum distances is necessary between adjacent airports to prevent obstructions in the operation of the aircraft.

Accessibility: It is an important criterion, not only for airline users, but also for the other section of the public. Proper accessibility reduces the overall travel time & hence it is an attractive feature for selecting an airport site.

Availability of land for future needs: This is necessary for future expansion needs.

Availability of utility services: Utility services like water supply, electricity & telephones are essential for an airport.
Regional plan: The site should fit appropriately into the overall regional plan & ultimately into the national plan of development.

Soil characteristics: Good pervious soil is desirable for effective drainage; a soil with good bearing capacity is desirable for construction of buildings & runways.

Deign of runway:

Runway design is concerned with planning the pattern and configuration of runways at an airport; it further includes the geometric elements of runways and their design. The number of runways at an airport depends on the volume of air traffic expected to use the facility. Orientation of a runway is its direction along its length and its positioning with respect to the direction of the wind prevailing at the airport site.

Geometrics of Runway:

- **Length**
- **Width**
- **Longitudinal gradient**
- **Rate of change of gradient**

- Transverse gradient
- Sight distance
- Runway shoulders
- Safety area

Orientation of a Runway:

The orientation of a runway is its direction at an airport; this is an important aspect in runway design & is primarily dependent on the wind characteristics at the airport site.

Head Wind: A runway is usually oriented in the direction of the prevailing winds; head wind means wind against & direction of the head or nose of the aircraft, while it is landing or taking off. The advantages of head wind are:

- Braking effect during landing helps the aircraft to come to a stop in a relatively short length of the runway.
- Greater lift on aircraft wings during takeoff makes the aircraft to rise above the ground using relatively the shorter length of the runway.

Cross wind components: it is not possible to obtain the head wind along the centre line of the runway on all the days of the year, thus for some period of the year, the wind blows at a certain angle with respect to the center line of the runway.

In such a case, while a component parallel to the center line of the runway is helpful in the operations, the component perpendicular to it, which is called the cross-wind component, is considered to be undesirable beyond a certain limit, this is because it can affect the safety of landing & takeoff of light & medium-weight aircraft. In general, cross-wind component should not exceed 25km/hour.

Wind coverage: This is defined as the percentage of time in a year during which the cross wind component is within the stipulated permissible limit.

For the purpose of calculating the wind coverage in any particular direction, a deviation up to +/- 11.25° is considered permissible.

Calm period: this is the period, expressed as percentage in a year, during which velocity is less than a stipulated minimum. This value is considered to be velocity of 6km/hour, which will have negligible effect.

Wind Rose: The average wind data of a design period (5 to 10 years) are represented in a graphical form by means of a chart, known as wind-rose. (it is so called because the plotted chart appears in the form of rose petals)

Wind rose diagrams may be plotted in two different ways:

- Type-I shows the direction & duration of the wind in percent in a year
- Type-II shows the direction, percent duration in a year & wind velocity or intensity.

Type-I Wind Rose:

A typical set of wind data (an average of say 5 years) for a site of an airport is given below :

Table3: Wind forecast

Wind direction	Duration of wind (%)			Total in each direction (%)
	6-25km/hour	25-50km/hour	50-75km/hour	
N	7.2	2.8	0.2	10.2
NNE	5.4	2.4	0.2	8
NE	2.7	0.7	0.6	4
ENE	1.2	0.5	0.1	1.8
E	0.7	0.3	0	1
ESE	0.4	0.2	0	0.6
SE	4.2	2.8	0.2	7.2
SSE	5.6	3.6	0	9.2
S	9.6	4.8	0	14.4
SSW	6.3	3.6	0.6	10.5
SW	3.6	1.9	0.5	6
WSW	1.2	0.6	0.2	2
W	0.5	0.1	0	0.6
WNW	0.3	0.1	0	0.4
NW	5.4	2	0	7.4
NNW	5	1.4	0.3	6.7
			Total:	90

Type I Wind Rose

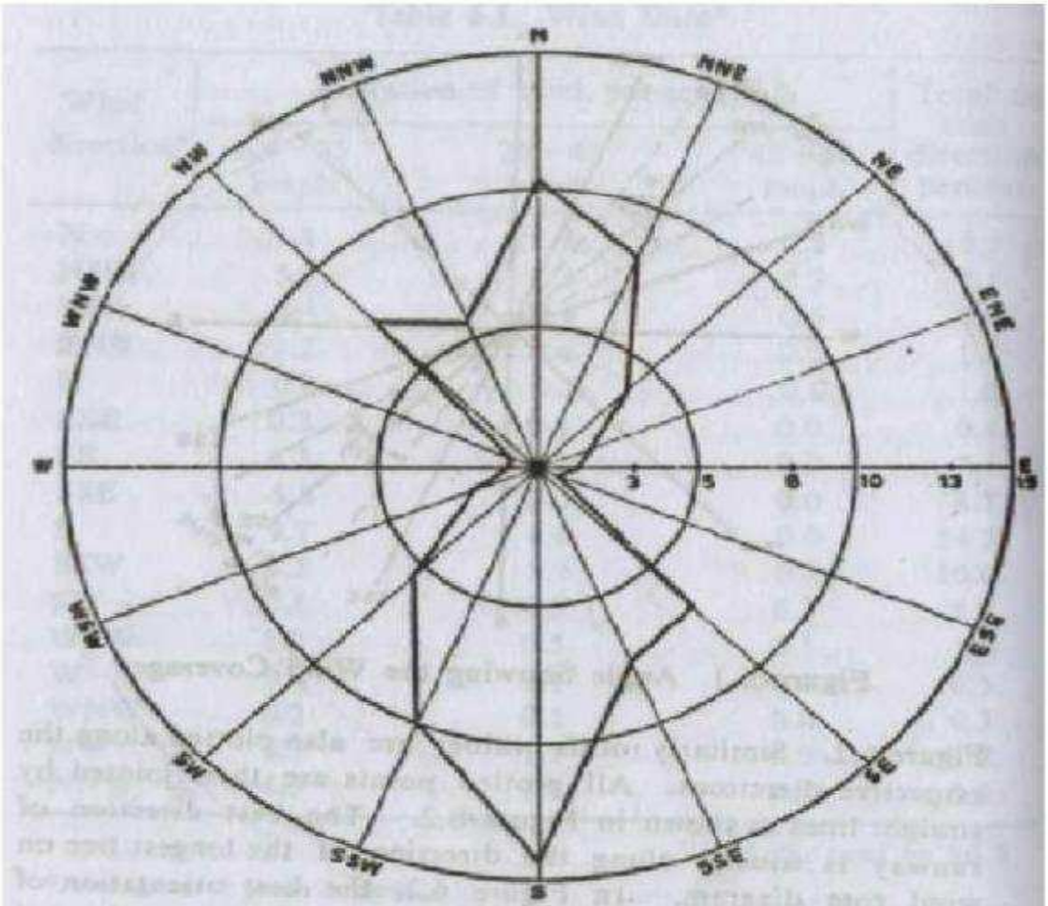

Figure 6.2 Wind Rose Diagram Type I

This type of wind rose is illustrated in Figure

- The radial lines indicate the wind direction and each circle represents the duration of wind.
- From the Table, it is observed that the total percentage of time in a year during which the wind blows from north direction is X percent. This value is plotted along the north direction.
- Similarly other values are also plotted along the respective directions,
- All plotted points are then jointed by straight lines as shown in Figure.
- The best direction of runway is usually along the direction of the longest line on wind rose diagram.
- In Figure the best orientation of runway is thus along NS direction.

Figure1: Wind rose diagram: Type I

Type-II Wind- Rose:

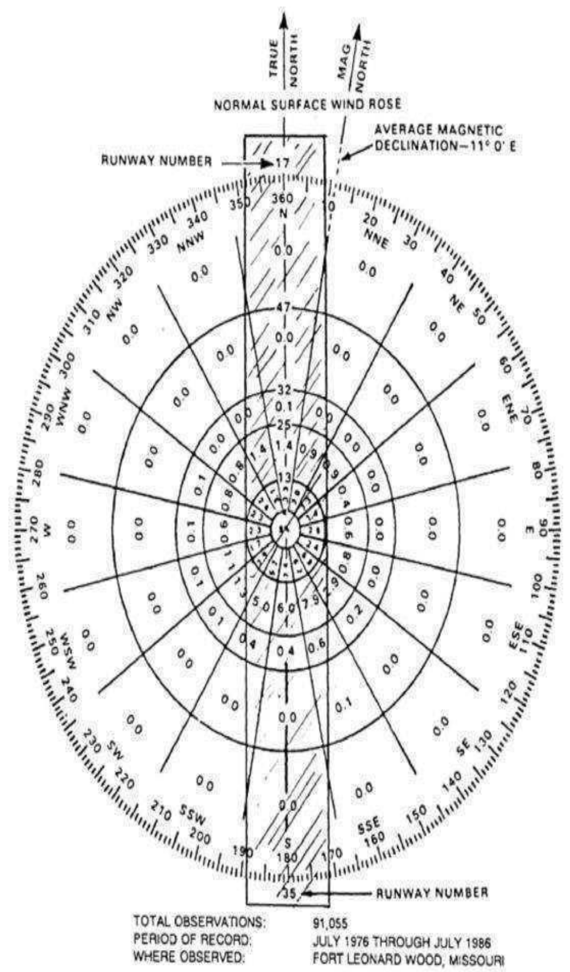

Figure 11-10. Determination of runway alignment by wind-rose analysis

Figure 2:-Wind-rose diagram- Type II

For the same data, type-II wind-rose is obtained as follows:

- **Concentric circles corresponding to 6, 25, 50 & 75km/hour of wind velocity are drawn to a convenient scale.**
- **The 16 radial directions are shown on the outermost circle as shown**
- **The respective wind durations for each direction are marked in the corresponding sector or part of it.**

The following manner to obtain the best orientation of the runway for these conditions:

- **A transparent paper template, rectangular in shape, is taken such that its length is a little more than the diameter of the outer most circles. The center line parallel to the length is drawn to represent the runway.**
- **Two more parallel lines are drawn to this line such that they are at a distance of 25km/hour on either side of the centerline, to the same scale used on the wind rose.**

- This template is placed on the wind rose such that their centers coincide
- The template is now turned & orientated in such a way that the sum of all the values of wind duration between the two outer parallel lines is the maximum value.
- The center of the template in this orientation is the best orientation of the runway
- The wind coverage percentage is obtained by summing up the percentages marked in the segments encompassed by the template.

Length of runway:

The length of runway has to be carefully determined for safe & efficient landing & takeoff of the various aircraft expected to use the airport.

Basic runway length: The length of the runway under standard prevalent conditions is known as the basic runway length. These conditions are:

- The airport is situated at sea-level
- The temperature at the airport is the standard value of 15˚C.
- The temperature along the way to the destination is also the standard value.
- The runway is level along its longitudinal direction
- No wind blows on the runway
- No wind blows even on the way to the destination
- The aircraft is loaded to its full capacity

The basic length of the runway is determined based on the performance characteristics of the aircraft during landing & takeoff. The following three cases are considered:

- Normal landing
- Normal takeoff
- Engine failure or emergency.

Correction in basic runway length

1. Correction for elevation:

As per the recommendation of ICAO (International Civil Aviation Organization), the basic runway length should be increased at the rate of 7 per center 300 m rise in elevation of airport above the mean sea level. This correction is required because the air density reduces as the elevation increases which in turn reduces the lift on the wings of the aircraft. Thus, the aircraft will require more ground speed to rise to the air and for achieving more speed; the longer length of runway will be required.

2. Correction for temperature:

The rise in airport reference temperature has the same effect as that of the increase in its elevation above mean sea-level. After the basic length is corrected for the elevation of airport, it is further increased at the rate of1% for every 1°C rise in airport reference temperature above the standard atmospheric temperature at that elevation.

Where T

1 = monthly mean of the average daily temperature for the hottest month of the year

2= monthly mean of the maximum daily temperature for the same month.

The standard temperature at the airport site can be determined by reducing the standard mean sea-level temperature of 15 0C at rate of 6.5°C per thousand meter rise in elevation.

Note:

The ICAO recommends that if the total correction for elevation plus temperature exceeds 35% of the basic runway length, the

Specific studies at the site by model tests should be carried out.

Correction for gradient:

The maximum difference in elevation between the highest and the lowest points of runway divided by the total length of runway is known as the

Effective gradient:

According to FAA (Federal Aviation Administration) of U.S.A., the runway length after being corrected for elevation and temperature should further be increased at the rate of 20% for every 1% of the effective gradient.

Taxiway design:-

Taxiway A taxiway is a path for aircraft at an airport connecting runways with aprons hangars terminals and other facilities.

Geometric Design Standards

a. Length of taxiway
b. Width of safety area
c. Longitudinal gradient
d. Transverse gradient
e. Rate of change of longitudinal gradient
f. Sight distance
g. Turning Width of taxiway
h. Radius

Length of Taxiway

- It should be as short as practicable.
- No specifications are recommended by any organization.

Width of taxiway

- Width of taxiway is lower than the runway width.
- The speed of an aircraft on a taxiway is also less than the runway.

Width of safety area

- **This area includes taxiway pavement on either side that may be partially paved plus the area that is graded and drained.**
- **A width of 7.5 m of shoulders adjacent to the pavement edges should be paved with light strength material.**

Longitudinal Gradient

- **ICAO recommends that the longitudinal gradient should not exceed 1.5% for A and B types and 3% for C D and E types.**

Transverse Gradient

- **This is essential for quick drainage of water.**
- **ICAO has recommended that the transverse gradient should not exceed 1.5% for A,B and C and C types and 2% for D and E types of airports. Rate of change of longitudinal gradient**
- **ICAO recommends that the rate of change of slope in longitudinal direction should not exceed 1% per 30 m length of vertical curve for A,B and C types and 1.2% for D and E types of airports.**

Sight distance

- **ICAO has recommended that the surface of taxiway must be visible from 3m height for a distance of 300m for A,B and C types and distance of 250 m be visible for 2.1m height for D and E types of airports. Turning radius**
- **Whenever there is a change in the direction of taxiway a horizontal curve is provided .**
- **The radius of horizontal curve is obtained by : R=V^2/125f V =speed in kmph coefficient of friction f =.13**

Horonjeff equation

R=.388w^2/T/2-S

- **W=wheel base of taxiway in meter**
- **T=width of taxiway pavement in meter S=distance between midway point of main gears and the edge of the taxiway pavement in meter for**
- **supersonic planes it is taken as 180m and for sub sonic it is taken as 120m.**

