Lecture-31

AIRPORT SCENARIO IN INDIA

Introduction

Since its beginning in the early twentieth century, civil aviation has become one of the most fascinating, important, and complex industries in the world. The civil aviation system, particularly its airports, has come to be the backbone of world transport and a necessity to twenty-first-century trade and commerce. In 2008, the commercial service segment of civil aviation, consisting of more than 900 airlines and 22,000 aircraft, carried more than 2 billion passengers and 85 million tons of cargo on more than 74 million flights to more than 1700 airports in more than 180 countries worldwide. Millions more private, corporate, and charter –general aviation‖ operations were conducted at thousands of commercial and general aviation airports throughout the world. In many parts of the world, commercial service and general aviation serve as the primary, if not the only method of transportation between communities.

The magnitude of the impact of the commercial air transportation industry on the world economy is tremendous, contributing more than $2.6 trillion in economic activity, equivalent to 8 percent of the world gross domestic product, and supporting 29 million jobs.

Air transport scenario in India

The first commercial flight in India was made on February 18, 1911 by Henri Piquet, a frenchman. The flight was planned from Allahabad to Naini junction which is a distance of 7 km L5 miles). Same year Sir George Loyd undertook the rganization of air flying between Bombay and Karachi. Air xvice between these cities were considered as purely mporary and was taken as a government venture.

In 1927 British government established Civil Aviation epartmenl and (his organization helped in building up of a w aerodromes and bringing up of some flying clubs. A gular weekly service commenced between Karachi and elhi in 1929 under Imperial Airways Service. In 1939 Tata \rways Limited started internal air services between Allahabad, Calcutta and Colombo. Later, Indian Trans-Continental Airways mited was formed for the foreign flights in 1933.

The second world War helped this country for having large tmber of technical personnel.

Air Transport Licensing Board came into being in 1946. Tata airlines changed its name as Air India Limited in July 1946 here were about eleven operating units by 1947. The nigbt rvic.es

* Under revision

commenced in 1949. For external air services, the Jvernment of India entered in agreement in November 1947, th a new formed organization, named as Ait India International mited. It inaugurated its first international service to London June 8, 1948 via Cairo and Geneva with a fleet of three
constellation-749 aircraft. The initial frequency of one flight a week was gradually stepped up to seven Super-Constellation services a week with alternate stops at Paris, Prague, Duesseidorf, Zurich, Geneva, - Rome, Cairo, Beirut and Damascus.

Master Committee 1952 recommended the formation of Civil Aviation Board as a statutary body. Air Transport Corporation Bill was passed on May 14, 1953. Under this bill two corporations were established, one for operating international services and the other for domestic services. The domestic operations were taken over by the Indian Airlines Corporation. Similarly, Air India. International Limited was renamed as Air India International Corporation. On August 1, 1953 airlines were nationalised.

In April 1960, Air India celebrated entry into the jet age by starting Boeing 707 services to London and later in May to New York—thus becoming the first Asian carrier to operate over the Atlantic.

In July 1967, the Government, of India set up the International Airports Committee under the chairmanship of Mr. J. R. D Tata to advise the Government regarding the improvement which are required in the existing international airports it India in view of the continuous growth of air traffic and the likely introduction of very large subsonic and supersonic aircrafts in near future. The interim report of the committee was submitted to the Government in April, 1968. On January 2, 1971, Indian Airlines inaugurated the daily Boeing 737 service on the Bombay-Calcutta and Delhi-Bombay sectors. The country for domestic flights is divided in to four flight information regions with centres at Delhi, Bombay Madras and Calcutta.

International Airport Authority of India (IAAI) was set u in April 1972 for the operation, management, planning an development of the four international airports.

The first commercial flight in India was made on February 18, 1911, when a French pilot Monseigneur Piguet flew airmails from Allahabad to Naini, covering a distance of about 10 km in as many minutes. Tata Services became Tata Airlines and then Air-India and spread its wings as Air-India International. The domestic aviation scene, however, was chaotic. When the American Tenth Air Force in India disposed of its planes at throwaway prices, 11 domestic airlines sprang up, scrambling for traffic that could sustain only two or three. In 1953, the government nationalized the airlines, merged them, and created Indian Airlines. For the next 25 years JRD Tata remained the chairman of Air-India and a director on the board of Indian Airlines. After JRD left, voracious unions mushroomed, spawned on the pork barrel jobs created by politicians. In 1999, A-I had 700 employees per plane; today it has 474 whereas other airlines have 350.

For many years in India air travel was perceived to be an elitist activity. This view arose from the –Maharajah‖ syndrome where, due to the prohibitive cost of air travel, the only people who could afford it were the rich and powerful.

In recent years, however, this image of Civil Aviation has undergone a change and aviation is now viewed in a different light - as an essential link not only for international travel and trade but also for providing connectivity to different parts of the country. Aviation is, by its very nature, a critical part of the infrastructure of the country and has important ramifications for the development of tourism and trade, the opening up of inaccessible areas of the country and for providing stimulus to business activity and economic growth.

Until less than a decade ago, all aspects of aviation were firmly controlled by the Government. In the early fifties, all airlines operating in the country were merged into either Indian Airlines or AirIndia and, by virtue of the Air Corporations Act, 1953; this monopoly was perpetuated for the next forty years. The Directorate General of Civil Aviation controlled every aspect of flying including granting flying licenses, pilots, certifying aircrafts for flight and issuing all rules and procedures governing Indian airports and airspace. Finally, the Airports Authority of India was entrusted with the responsibility of managing all national and international air ports and administering every aspect of air transport operation through the Air Traffic Control. With the opening up of the Indian economy in the early Nineties, aviation saw some important changes. Most importantly, the Air Corporation Act was repealed to end the monopoly of the public sector and private airlines were reintroduced.

Objectives of Civil Aviation Ministry

a) To ensure aviation safety, security

b) Effective regulation of air transport in the country in the liberalized environment

c) Safe, efficient, reliable and widespread quality air transport services are provided at reasonable prices

d) Flexibility to adapt to changing needs and circumstances

e) To provide all players a level-playing field

f) Encourage Private participation

g) Encourage Trade, tourism and overall economic activity and growth

h) Security of civil aviation operations is ensured through appropriate systems, policies, and practices

* Under revision

Lecture-32

STAGES OF DEVELOPMENT

Introduction

An airport system plan is a representation of the aviation facilities required to meet the immediate and future needs of a metropolitan area, region, state, or country. The system plan presents the recommendations for the general location and characteristics of new airports and heliports and the nature of expansion for existing ones to meet forecasts of aggregate demand. It identifies the aviation role of existing and recommended new airports and facilities. It includes the timing and estimated costs of development and relates airport system planning to the policy and objectives of the relevant jurisdiction. Its overall purpose is to determine the extent, type, nature, location, and timing of airport development needed to establish a viable, balanced, and integrated system of airports. It also provides the basis for detailed airport planning such as that contained in the airport master plan.

The airport system plan provides both broad and specific policies, plans, and programs required to establish a viable and integrated system of airports to meet the needs of the region. The objectives of the system plan include:

1. The orderly and timely development of a system of airports adequate to meet present and future aviation needs and to promote the desired pattern of regional growth relative to industrial, employment, social, environmental, and recreational goals.
2. The development of aviation to meet its role in a balanced and multimodal transportation system to foster the overall goals of the area as reflected in the transportation system plan and comprehensive development plan.
3. The protection and enhancement of the environment through the location and expansion of aviation facilities in a manner which avoids ecological and environmental impairment.
4. The provision of the framework within which specific airport programs may be developed consistent with the short- and long-range airport system requirements.
5. The implementation of land-use and airspace plans which optimize these resources in an often constrained environment.
6. The development of long-range fiscal plans and the establishment of priorities for airport financing within the governmental budgeting process.

7. The establishment of the mechanism for the implementation of the system plan through the normal political framework, including the necessary coordination between governmental agencies, the involvement of both public and private aviation and nonaviation interests, and compatibility with the content, standards, and criteria of existing legislation. The airport system planning process must be consistent with state, regional, or national goals for transportation, land use, and the environment.

The elements in a typical airport system planning process include the following:
1. Exploration of issues that impact aviation in the study area
2. Inventory of the current system
3. Identification of air transportation needs
4. Forecast of system demand
5. Consideration of alternative airport systems
6. Definition of airport roles and policy strategies
7. Recommendation of system changes, funding strategies, and airport development
8. Preparation of an implementation plan

Although the process involves many varied elements, the final product will result in the identification, preservation, and enhancement of the aviation system to meet current and future demand. The ultimate result of the process will be the establishment of a viable, balanced, and integrated system of airports.

Airport Classification

Airports are presently classified in the following manner:
1. International Airports:
2. Custom Airports:
3. Model Airports:
4. Other Domestic Airports:
5. Civil Enclaves in Defence Airport:

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Lecture-33

SITE SELECTION

Introduction

The emphasis in airport planning is normally on the expansion and improvement of existing airports. However if an existing airport cannot be expanded to meet the future demand or the need for a new airport is identified in an airport system plan, a process to select a new airport site may be required.

- ✓ Identification
- ✓ Screening
- ✓ Operational capability
- ✓ Capacity potential
- ✓ Ground access
- ✓ Development costs
- ✓ Environmental consequences
- ✓ Compatibility with area-wide planning
- ✓ Selection

THE AIRPORT MASTER PLAN

An airport master plan is a concept of the ultimate development of a specific airport. The term development includes the entire airport area, both for aviation and nonaviation uses, and the use of land adjacent to the airport. It presents the development concept graphically and contains the data and rationale upon which the plan is based. Master plans are prepared to support expansion and modernization of existing airports and guide the development of new airports.

The overall objective of the airport master plan is to provide guidelines for future development which will satisfy aviation demand in a financially feasible manner and be compatible with the environment, community development, and other modes of transportation.

More specifically it is a guide for

1. Developing the physical facilities of an airport
2. Developing land on and adjacent to the airport
3. Determining the environmental effects of airport construction and operations

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4. Establishing access requirements

5. Establishing the technical, economic and financial feasibility of proposed developments through a thorough investigation of alternative concepts

6. Establishing a schedule of priorities and phasing for the improvements proposed in the plan

7. Establishing an achievable financial plan to support the implementation schedule

8. Establishing a continuing planning process which will monitor conditions and adjust plan recommendations as circumstances warrant

Guidelines for completing an airport master plan are described by ICAO and in the United States by. A master plan report is typically organized as follows:

- ✓ Master plan vision, goals, and objectives
- ✓ Inventory of existing conditions
- ✓ Forecast of aviation demand
- ✓ Demand/capacity analysis and facility requirements
- ✓ Alternatives development
- ✓ Preferred development plan
- ✓ Implementation plan
- ✓ Environmental overview
- ✓ Airport plans package
- ✓ Stakeholder and public involvement

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Lecture-34

OBSTRUCTION AND ZONING LAWS

IMAGINARY SURFACES

In order to determine whether an object is an obstruction to air navigation, several imaginary surfaces are established with relation to the airport and to each end of a runway. The size of the imaginary surfaces depends on the category of each runway (e.g., utility or transport) and on the type of approach planned for that end of the runway (e.g., visual, nonprecision instrument, or precision instrument).

The principal imaginary surfaces are shown in Fig. 6-25. They are described as follows:

1. ***Primary surface.*** The primary surface is a surface longitudinally centered on a runway. When the runway is paved, the primary surface extends 200 ft beyond each end of the runway. When the runway is unpaved, the primary surface coincides with each end of the runway. The elevation of the primary surface is the same as the elevation of the nearest point on the runway centerline.

2. ***Horizontal surface.*** The horizontal surface is a horizontal plane 150 ft above the established airport elevation, the perimeter of which is constructed by swinging arcs of specified radii from the center of each end of the primary surface of each runway and connecting each arcs by lines tangent to those arcs.

3. ***Conical surface.*** The conical surface is a surface extending outward and upward from the periphery of the horizontal surface at a slope of 20 horizontal to 1 vertical for a horizontal distance of 4000 ft.

4. ***Approach surface***. The approach surface is a surface longitudinally centered on the extended runway centerline and extending outward and upward from each end of a runway at a designated slope based upon the type of available or planned approach to the runway.

5. ***Transitional surface.*** Transitional surfaces extend outward and upward at right angles to the runway centerline plus the runway centerline extended at a slope of 7 to 1 from the sides of the primary surface up to the horizontal surface and from the sides of the approach surfaces. The width of the transitional surface provided from each edge of the approach surface is 5000 ft.

Lecture-35

AIRCRAFT CHARACTERISTICS

Introduction

One of the great challenges for airport planning and design is creating facilities that accommodate a very wide variety of aircraft. Aircraft vary widely in terms of their physical dimensions and performance characteristics, whether they be operated for commercial air service, cargo, or general aviation activities.

There are a large number of specifications for which aircraft may be categorized. Depending on the portion of the area of the airport, certain aircraft specifications become more critical. For example, aircraft weight is important for determining the thickness and strengths of the runway, taxiway, and apron pavements, and affects the takeoff and landing runway length requirements at an airport, which in turn to a large extent influences planning of the entire airport property.

The wingspan and the fuselage length influence the size of parking aprons, which in turn influences the configuration of the terminal buildings. Wingspan and turning radii dictate width of runways and taxiways, the distances between these traffic ways, and affects the required turning radius on pavement curves. An aircraft‘s passenger capacity has an important bearing on facilities within and adjacent to the terminal building.

Since the initial success of the Wright Flyer in 1903, fixed-wing aircraft have gone through more than 100 years of design enhancements, resulting in vastly improved performance, including the ability to fly at greater speeds and higher altitudes over larger ranges with more revenue generating carrying capacity (known as payload) at greater operating efficiencies. These improvements are primarily the results of the implementation of new technologies into aircraft specifications, ranging from materials from which the airframes are built, to the engines that power the aircraft. Of great challenge to airport planning and design, historically has been to adapt the airport environment to accommodate changes in aircraft physical and performance specifications. For example:

• The introduction of ―cabin-class‖ aircraft, such as the Douglas DC-3, in the mid-1930s resulted in the need for airports to construct longer, paved runways from the shorter grass strips that previously existed.

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• The introduction of aircraft equipped with turbofan and turbojet engines in the late 1950s added requirements for longer and stronger runways, facilities to mitigate jet-blast, and policies to reduce the impact of aircraft noise at and around the airport.

• The introduction of ―jumbo-jet‖ or ―heavy‖ aircraft, such as the Boeing-747, in the late 1960s added new requirements for runway specifications, as well as terminal area design requirements for accommodating large volumes of passengers and cargo.

• The proliferation of regional jet aircraft, introduced because of more efficient engine technologies, resulted in the need for airports to modify many terminal areas that had accommodated larger jets or smaller turbo-prop aircraft.

Most recently, the introduction of the world‘s largest passenger aircraft, the Airbus A-380, as well as the smallest of certified general aviation jet aircraft, continues to affect design specifications of airport airfield and terminal areas.

Table below provides a summary of some of the important aircraft characteristics of some of the aircraft that make up the world‘s commercial airline fleet. Many regional airlines use smaller aircraft with less than 50 seats, while the world‘s major airlines use very large aircraft, with potential configurations for more than 800 seats.

Manufacturer	**Aircraft**	**Wing-span in m**	**Tail Height in m**	**Length in m**	**CMG in m**	**Wheel-base in m**	**MGW Outer to Outer in m**	**MTOW in kg**	**V_{REF} / Approach Speed**
Airbus	A-300	44.83	16.72	53.61	22.86	18.6	11	165000	137
Airbus	A-300 -600	(44.84)	(16.7)	(54.1)	(22.87)	(18.6)	(10.96)	(170500)	137
Airbus	A-310	(43.9)	(15.87)	(46.66)	(19.49)	(15.22)	(10.96)	(164000)	139
Airbus	A-318	(34.1)	(12.89)	(31.45)	(12.91)	(10.25)	(8.95)	(68000)	121
Airbus	A-318 Sharklet	(35.8)	(12.89)	(31.45)	(12.91)	(10.25)	(8.95)	(68000)	121
Airbus	A-319	(34.1)	(12.11)	(33.84)	(13.7)	(11.04)	(8.95)	(75500)	138
Airbus	A-320	(34.1)	(12.08)	(37.57)	(15.3)	(12.64)	(8.95)	(78000	136
Boeing	707-320B	(44.4)	(12.8)	(46.6)	(20.85)		(8.02)	(151319)	128
Boeing	707-200	(28.40)	(9.08)	(37.80)	(17.00)	(17.62)	(5.90)	(54,885)	139

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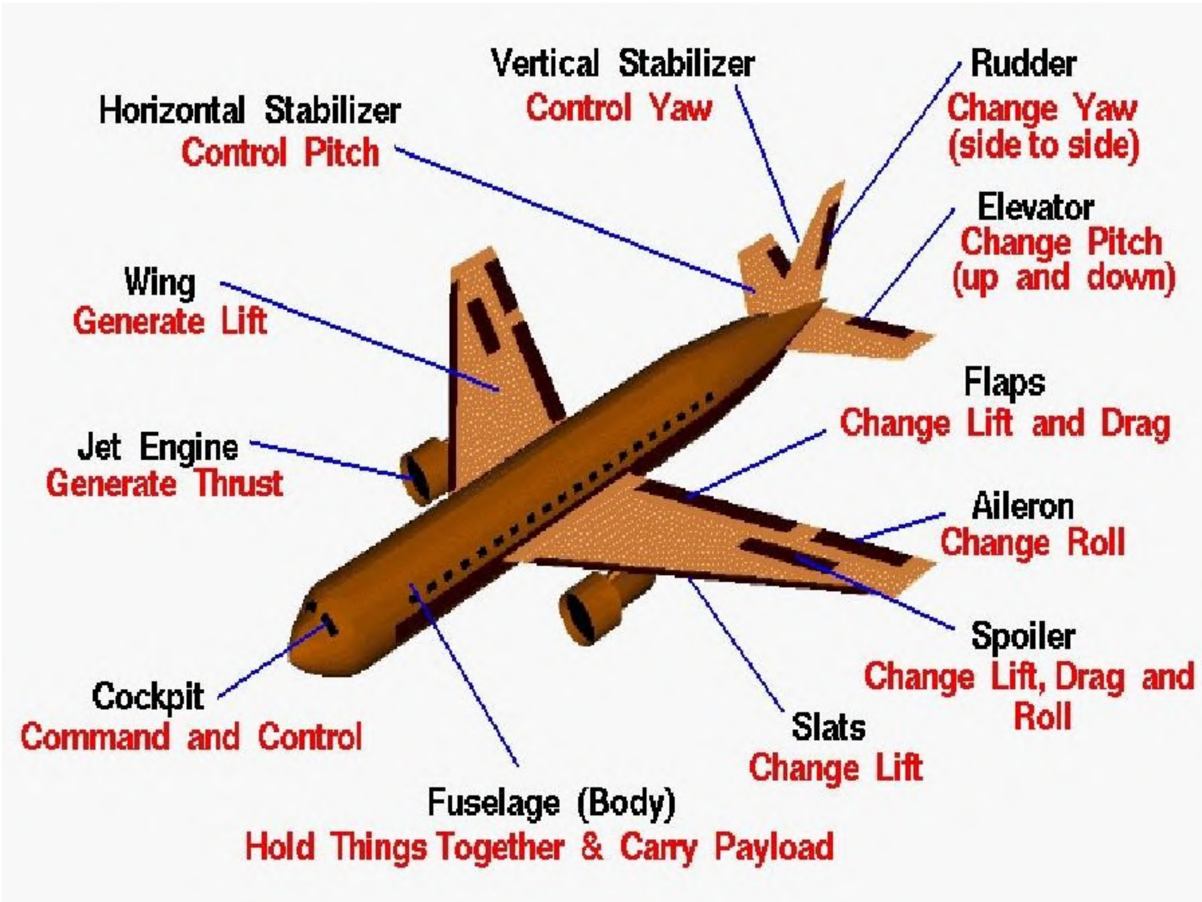

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Lecture-36

ELEMENTS OF RUNWAY

Introduction

A runway is a rectangular area on the airport surface prepared for the takeoff and landing of aircraft. An airport may have one runway or several runways which are sited, oriented, and configured in a manner to provide for the safe and efficient use of the airport under a variety of conditions. Several of the factors which affect the location, orientation, and number of runways at an airport include local weather conditions, particularly wind distribution and visibility, the topography of the airport and surrounding area, the type and amount of air traffic to be serviced at the airport, aircraft performance requirements, and aircraft noise.

Runway Configurations

The term ―runway configuration‖ refers to the number and relative orientations of one or more runways on an airfield. Many runway configurations exist. Most configurations are combinations of several basic configurations. The basic configurations are

(1) single runways,

(2) parallel runways,

(3) intersecting runways, and

(4) open-V runways.

Single Runway

It has been estimated that the hourly capacity of a single runway in **VFR** (visual flight rules) conditions is somewhere between 50 and 100 operations per hour, while in **IFR** (instrument flight rules) conditions this capacity is reduced to 50 to 70 operations per hour, depending on the composition of the aircraft mix and navigational aids available.

Parallel Runways

The capacities of parallel runway systems depend on the number of runways and on the spacing between the runways. Two, three, and four parallel runways are common. The spacing between parallel runways varies widely. For the purpose of this discussion, the spacing is classified as close, intermediate, and far, depending on the centreline separation between two parallel runways. Close parallel runways are spaced from a minimum of 700 ft (for air carrier airports) to less than 2500 ft. In IFR conditions an operation of one runway is dependent on the operation of

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other runway. Intermediate parallel runways are spaced between 2500 ft to less than 4300 ft. In IFR conditions an arrival on one runway is independent of a departure on the other runway. Far parallel runways are spaced at least 4300 ft apart. If the terminal buildings are placed between parallel runways, runways are always spaced far enough apart to allow room for the buildings, the adjoining apron, and the appropriate taxiways. When there are four parallel runways, each pair is spaced close, but the pairs are spaced far apart to provide space for terminal buildings.

In VFR conditions, close parallel runways allow simultaneous arrivals and departures, that is, arrivals may occur on one runway while departures are occurring on the other runway. Aircraft operating on the runways must have wingspans less than 171 ft for centerline spacing at the minimum of 700 ft. The hourly capacity of a pair of parallel runways in VFR conditions varies greatly from 60 to 200 operations per hour depending on the aircraft mix and the manner in which arrivals and departures are processed on these runways. Similarly, in IFR conditions the hourly capacity of a pair of closely spaced parallel runways ranges from 50 to 60 operations per hour, of a pair of intermediate parallel runways from 60 to 75 operations per hour, and for a pair of far parallel runways from 100 to 125 operations per hour.

Intersecting Runways

Many airports have two or more runways in different directions crossing each other. These are referred to as intersecting runways. Intersecting runways are necessary when relatively strong winds occur from more than one direction, resulting in excessive crosswinds when only one runway is provided. When the winds are strong, only one runway of a pair of intersecting runways can be used, reducing the capacity of the airfield substantially. If the winds are relatively light, both runways can be used simultaneously. The capacity of two intersecting runways depends on the location of the intersection (i.e., midway or near the ends), the manner in which the runways are operated for takeoffs and landings, referred to as the runway use strategy, and the aircraft mix. The farther the intersection is from the takeoff end of the runway and the landing threshold, the lower is the capacity. The highest capacity is achieved when the intersection is close to the takeoff and landing threshold.

Open-V Runways

Runways in different directions which do not intersect are referred to as open-V runways. Like intersecting runways, open-V runways revert to a single runway when winds are strong from one direction. When the winds are light, both runways may be used simultaneously. The strategy which yields the highest capacity is when operations are away from the V and this is referred to as a diverging pattern. In VFR the hourly capacity for this strategy ranges from 60 to 180 operations per hour, and in IFR the corresponding capacity is from 50 to 80 operations per hour. When operations are toward the V it is referred to as a converging pattern and the capacity is reduced to 50 to 100 operations per hour in VFR and to between 50 and 60 operations per hour in IFR.

Combinations of Runway Configurations

From the standpoint of capacity and air traffic control, a single-direction runway configuration is most desirable. All other things being equal, this configuration will yield the highest capacity compared with other configurations. For air traffic control the routing of aircraft in a single direction is less complex than routing in multiple directions. Comparing the divergent configurations, the open-V runway pattern is more desirable than an intersecting runway configuration. In the open-V configuration an operating strategy that routes aircraft away from the V will yield higher capacities than if the operations are reversed. If intersecting runways cannot be avoided, every effort should be made to place the intersections of both runways as close as possible to their thresholds and to operate the aircraft away from the intersection rather than toward the intersection.

Lecture-37

ORIENTATION AND CONFIGURATION

Introduction

The orientation of a runway is defined by the direction, relative to magnetic north, of the operations performed by aircraft on the runway. Typically, but not always, runways are oriented in such a manner that they may be used in either direction. It is less preferred to orient a runway in such a way that operating in one direction is precluded, normally due to nearby obstacles.

In addition to obstacle clearance considerations, which will be discussed later in this chapter, runways are typically oriented based on the area‘s wind conditions. As such, an analysis of wind is essential for planning runways. As a general rule, the primary runway at an airport should be oriented as closely as practicable in the direction of the prevailing winds. When landing and taking off, aircraft are able to maneuver on a runway as long as the wind component at right angles to the direction of travel, the crosswind component, is not excessive.

The FAA recommends that runways should be oriented so that aircraft may be landed at least 95 percent of the time with allowable crosswind components not exceeding specified limits based upon the airport reference code associated with the critical aircraft that has the shortest wingspan or slowest approach speed. When the wind coverage is less than 95 percent a crosswind runway is recommended.

The allowable crosswind is 10.5 kn (12 mi/h) for Airport Reference Codes A-I and B-I, 13 kn (15 mi/h) for Airport Reference Codes A-II and B-II, 16 kn (18.5 mi/h) for Airport Reference Codes A-III, B-III, C-I, C-II, C-III and C-IV, and 20 knots (23 mph) for Airport Reference Codes A-IV through D-VI [5].

ICAO also specifies that runways should be oriented so that aircraft may be landed at least 95 percent of the time with crosswind components of 20 kn (23 mph) for runway lengths of 1500 m more, 13 kn (15 mi/h) for runway lengths between 1200 and 1500 m, and 10 kn (11.5 mi/h) for runway lengths less than 1200 m.

Once the maximum permissible crosswind component is selected, the most desirable direction of runways for wind coverage can be determined by examination of the average wind characteristics at the airport under the following conditions:

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1. The entire wind coverage regardless of visibility or cloud ceiling
2. Wind conditions when the ceiling is at least 1000 ft and the visibility is at least 3 mi
3. Wind conditions when ceiling is between 200 and 1000 ft and/or the visibility is between . and 3 mi.

The first condition represents the entire range of visibility, from excellent to very poor, and is termed the all weather condition. The next condition represents the range of good visibility conditions not requiring the use of instruments for landing, termed visual meteorological condition (VMC). The last condition represents various degrees of poor visibility requiring the use of instruments for landing, termed instrument meteorological conditions (IMC). The 95 percent criterion suggested by the FAA and ICAO is applicable to all conditions of weather; nevertheless it is still useful to examine the data in parts whenever this is possible.

In the United States, weather records can be obtained from the Environmental Data and Information Service of the National Climatic Center at the National Oceanic and Atmospheric Administration located in Ashville, N.C., or from various locations found on the Internet.

Weather data are collected from weather stations throughout the United States on an hourly basis and recorded for analysis. The data collected include ceiling, visibility, wind speed, wind direction, storms, barometric pressure, the amount and type of liquid and frozen precipitation, temperature, and relative humidity. A report illustrating the tabulation and representation of some of the data of use in airport studies was prepared for the FAA. The weather records contain the percentage of time certain combinations of ceiling and visibility occur (e.g., ceiling, 500 to 900 ft; visibility, 3 to 6 mi), and the percentage of time winds of specified velocity ranges occur from different directions (e.g., from NNE, 4 to 7 mi/h). The directions are referenced to true north.

The Wind Rose

The appropriate orientation of the runway or runways at an airport can be determined through graphical vector analysis using a wind rose. A standard wind rose consists of a series of concentric circles cut by radial lines using polar coordinate graph paper. The radial lines are drawn to the scale of the wind magnitude such that the area between each pair of successive lines is centered on the wind direction.

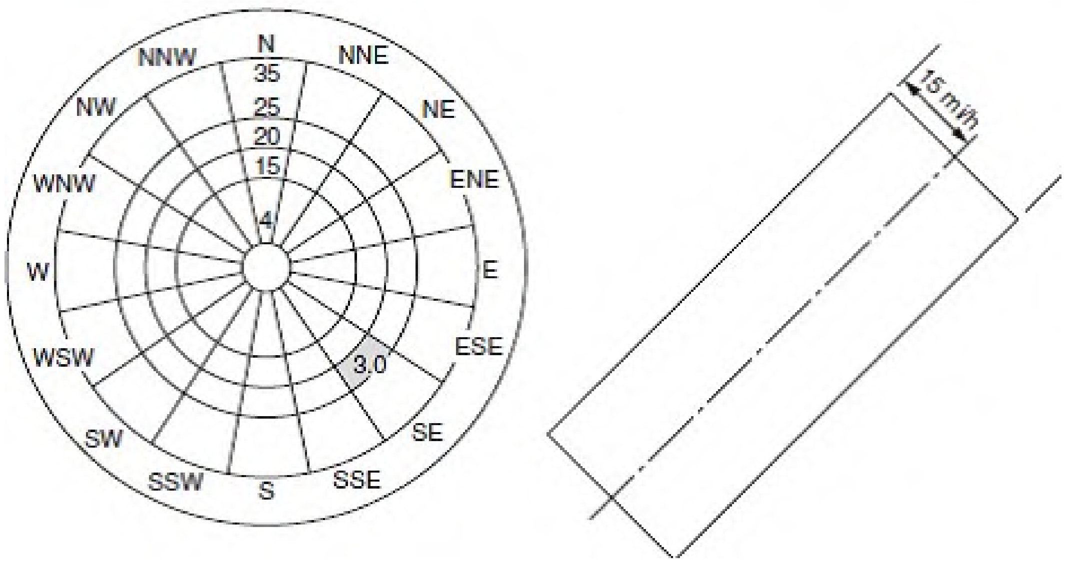

FIGURE: Wind rose coordinate system and template.

The shaded area indicates that the wind comes from the southeast (SE) with a magnitude between 20 and 25 mi/h. A template is also drawn to the same radial scale representing the crosswind component limits. A template drawn with crosswind component limits of 15 mi/h is shown on the right side of Fig. above. On this template three equally spaced parallel lines have been plotted. The middle line represents the runway center line, and the distance between the middle line and each outside line is, to scale, the allowable crosswind component (in this case, 15 mi/h). The template is placed over the wind rose in such a manner that the center line on the template passes through the center of the wind rose.

By overlaying the template on the wind rose and rotating the centreline of the template through the origin of the wind rose one may determine the percentage of time a runway in the direction of the centerline of the template can be used such that the crosswind component does not exceed 15 mi/h. Optimum runway directions can be determined from this wind rose by the use of the template, typically made on a transparent strip of material. With the center of the wind rose as a pivot point, the template is rotated until the sum of the percentages included between the outer lines is a maximum. If a wind vector from a segment lies outside either outer line on the template for the given direction of the runway, that wind vector must have a crosswind component which exceeds the allowable crosswind component plotted on the template. When one of the outer lines on the template divides a segment of wind direction, the fractional part is estimated visually to the nearest 0.1 percent. This procedure is consistent with the accuracy of the wind data and

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assumes that the wind percentage within the sector is uniformly distributed within that sector. In practice, it is usually easier to add the percentages contained in the sectors outside of the two outer parallel lines and subtract these from 100 percent to find the percentage of wind coverage.

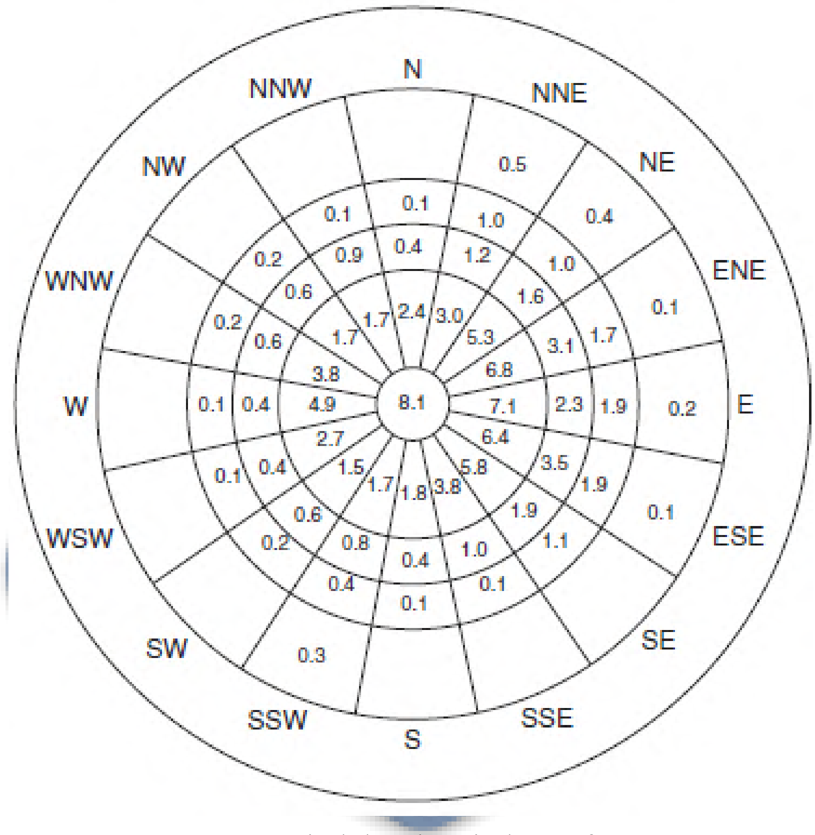


FIGURE: Wind data in wind rose format.

Lecture-38

BASIC RUNWAY LENGTH AND CORRECTIONS

Introduction

Length of runway decided taking following assumptions:

- Airport altitude at sea level
- Temperature at airport is standard (15^0C)
- Runway is level in longitudinal direction
- No wind is blowing on runway
- No wind is blowing enroute to destination
- Aircraft is loaded to its full capacity
- Enroute temperature standard

The basic runway length is determined form the performance characteristics of aircraft using airport. The following cases are usually considered

Normal landing case

Normal takeoff case

Engine failure case

For jet engine aircraft all three cases are considered but for piston engine air craft first and third case are usually considered. The longest runway length is finally adopted.

The landing case require that aircraft should come to stop within 60% of the landing distance. The full strength pavement is provided for entire landing distance.

The normal takeoff requires a clear way which is an area beyond the runway and is alignment with the centre line of the runway. The width of the clear way is not less than 150m (500 ft) and is kept free from obstruction. The clearway ground area any object should not protrude a plane upward at a slope of 1.25% from the runway end.

Engine failure case may require either a clearway or a stop way or both. Stopway is defined as the area beyond runway and centrally located in alignment with the centreline of the runway. It is used for decelerating the aircraft to stop during aborted takeoff. The strength of the stopway should be sufficient to carry the weight of the aircraft without casing any structural damage. If engine fail at a speed less than the designated engine failure speed, the pilot decelerate the

aircraft and use the stopway. If however engine fails at a speed higher than the designated speed, there is no other option to pilot take-off. The pilot may latter take turn and make a landing.
For piston engine aircrafts full strength pavement is provided for entire takeoff distance and the accelerated stop distance.

Correction for elevation, temperature and gradient

Airports are constructed in different elevation different atmospheric temperature and gradient, in contrast to the assumption made for basic runway length. Therefore correction required for changes in each components.

Correction in elevation

All other things being equal, the higher the field elevation of the airport, results the less dense the atmosphere, requiring longer runway lengths for the aircraft to get to the appropriate groundspeed to achieve sufficient lift for takeoff. For airports at elevation above sea level, the design runway length is 300 ft plus 0.03 ft for every foot above sea level. ICAO recommends the basic runway length should increase at rate of 7% per 100 m rise in elevation over MSL.

Correction in temperature

With rise of reference temperature same effect is there as that of elevation. The airport reference temperature defined as monthly mean of average daily temperature (T_a) for the hottest month of the year plus one third the difference of this temperature and monthly mean of the maximum daily temperature(T_w) for same month of the year.

Reference Temperature = $T_a + (T_w - T_a)/3$

ICAO recommends the basic runway length after have been corrected for elevation, should further increase at the rate of 1% for every 1^0C increase of reference temperature.
If both correction increases more than 35% ICAO recommended specific site study should be conducted.

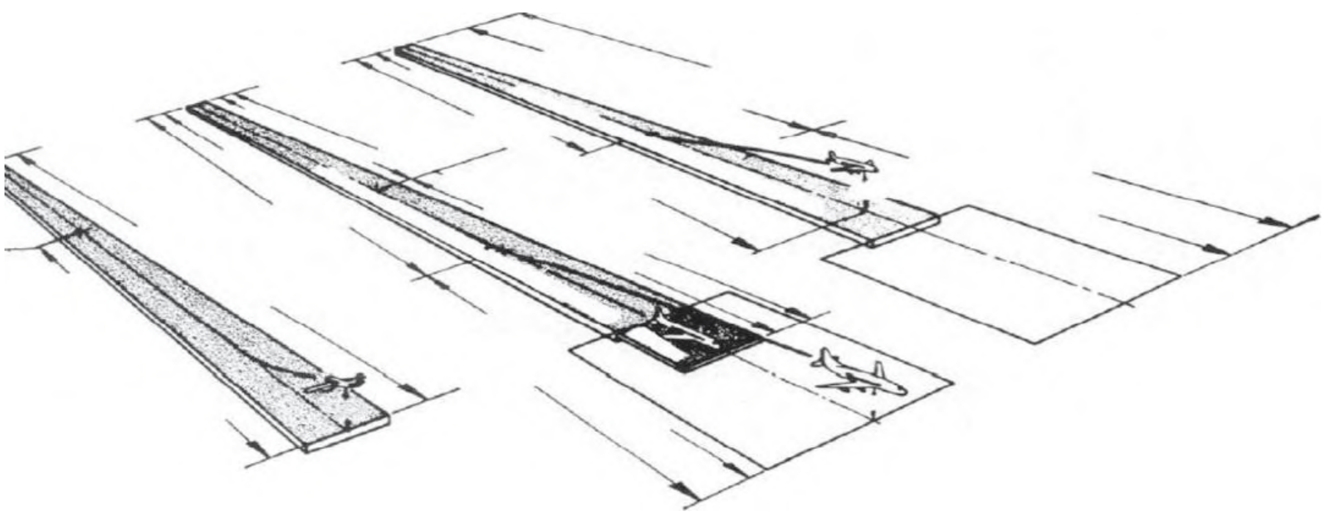
Correction for gradient

Steeper gradient require greater consummation of energy and longer length of runway to attain the desired speed. ICAO does not recommend any correction. FAA recommend after correction for elevation and temperature a further increase in runway length at arte of 20% for every 1 percent effective gradient.

Effective gradient is defined taking maximum difference between elevation between lowest point and highest point in the runway divided by length of the runway.

Surface Wind

Wind speed and direction at an airport also have a significance on runway length requirements. Simply, the greater the headwind the shorter the runway length required, and the greater the tailwind the longer the runway required. Further, the presence of crosswinds will also increase the amount of runway required for takeoff and landing. From the perspective of the planner, it is often estimated that for every 5 km of headwind, required runway length is reduced by approximately 3 percent and for every 7 km of tailwind, runway length requirements increase by approximately 7 percent. For airport planning purposes runway lengths are often designed assuming calm wind conditions.



Lecture-39

GEOMETRIC ELEMENTS DESIGN

Taxiways and Taxi lanes

Taxiways are defined paths on the airfield surface which are established for the taxiing of aircraft and are intended to provide a linkage between one part of the airfield and another. Basically it established the connection between runway, terminal building and hanger. The term ―dual parallel taxiways‖ refers to two taxiways parallel to each other on which airplanes can taxi in opposite directions. An apron taxiway is a taxiway located usually on the periphery of an apron intended to provide a through taxi route across the apron. A taxi lane is a portion of the aircraft parking area used for access between the taxiways and the aircraft parking positions. ICAO defines an aircraft stand taxi lane as a portion of the apron intended to provide access to the aircraft stands only.

In order to provide a margin of safety in the airport operating areas, the traffic ways must be separated sufficiently from each other and from adjacent obstructions. Minimum separations between the centerlines of taxiways, between the centerlines of taxiways and taxi lanes, and between taxiways and taxi lanes and objects are specified in order that aircraft may safely maneuver on the airfield.

Taxiway and Taxilane Separation Requirements

FAA Separation Criteria

The separation criteria adopted by the FAA are predicated upon the wingtips of the aircraft for which the taxiway and taxilane system have been designed and provide a minimum wingtip clearance on these facilities. The required separation between taxiways, between a taxiway and a taxilane, or between a taxiway and a fixed or movable object requires a minimum wingtip clearance of 0.2 times the wingspan of the most demanding aircraft in the airplane design group plus 10 ft. This clearance provides a minimum taxiway centerline to a parallel taxiway centerline or taxilane centerline separation of 1.2 times the wingspan of the most demanding aircraft plus 10 ft, and between a taxiway centerline and a fixed or movable object of 0.7 times the wingspan of the most demanding aircraft plus 10 ft. The taxilane centerline to a parallel taxilane centerline or fixed or movable object separation in the terminal area is predicated on a wingtip clearance of approximately half of that required for an apron taxiway. This reduction in clearance is based on the consideration that taxiing speed is low in this area, taxiing is precise, and special guidance techniques and devices are provided. This requires a wingtip clearance or wingtip-to-object clearance of 0.1 times the wingspan of the most demanding aircraft plus 10 ft.

Sight Distance and Longitudinal Profile

As in the case of runways, the number of changes in longitudinal profile for taxiways is limited by sight distance and minimum distance between vertical curves. The FAA does not specify line of sight requirements for taxiways other than those discussed earlier related to runway and taxiway intersections. However, the sight distance along a runway from an intersecting taxiway needs to be sufficient to allow a taxiing aircraft to enter or cross the runway safely. The FAA specifies that from any point on the taxiway centerline the difference in elevation between that point and the corresponding point on a parallel runway, taxiway, or apron edge is 1.5 percent of the shortest distance between the points. ICAO requires that the surface of the taxiway should be seen for a distance of 150 m from a point 1.5 m above the taxiway for aerodrome code letter A runways, for a distance of 200 m from a point 2 m above the taxiway for aerodrome code letter B runways, and for a distance of 300 m from a point 3 m above the taxiway for aerodrome code letter C, D, or E runways. In regard to longitudinal profile of taxiways, the ICAO does not specify the minimum distance between the points of intersection of vertical curves. The FAA specifies that the minimum distance for both utility and transport category airports should be not less than the product of 100 ft multiplied by the sum of the absolute percentage values of change in slope.

Exit Taxiway Geometry

The function of exit taxiways, or runway turnoffs as they are sometimes called, is to minimize runway occupancy by landing aircraft. Exit taxiways can be placed at right angles to the runway or some other angle to the runway. When the angle is on the order of 30°, the term high-speed exit is often used to denote that it is designed for higher speeds than other exit taxiway configurations. In this chapter, specific dimensions for high-speed exit, right-angle exit (low-speed) taxiways are presented.

Aircraft paths in the test approximated a spiral. A compound curve is relatively easy to establish in the field and begins to approach the shape of a spiral, thus the reason for suggesting a compound curve. The following pertinent conclusions were reached as a result of the tests [13]:

1. Transport category and military aircraft can safely and comfortably turn off runways at speeds on the order of 60 to 65 mi/h on wet and dry pavements.
2. The most significant factor affecting the turning radius is speed, not the total angle of turn or passenger comfort.
3. Passenger comfort was not critical in any of the turning movements.
4. The computed lateral forces developed in the tests were substantially below the maximum lateral forces for which the landing gear was designed.
5. Insofar as the shape of the taxiway is concerned, a slightly widened entrance gradually tapering to the normal width of taxiway is preferred. The widened entrance gives the pilot more latitude in using the exit taxiway.
6. Total angles of turn of 30° to 45° can be negotiated satisfactorily. The smaller angle seems to be preferable because the length of the curved path is reduced, sight distance is improved, and less concentration is required on the part of the pilots.
7. The relation of turning radius versus speed expressed by the formula below will yield a smooth, comfortable turn on a wet or dry pavement when f is made equal to 0.13.
8. The curve expressed by the equation for $R2$ should be preceded by a larger radius curve $R1$ at exit speeds of 50 to 60 mi/h. The larger radius curve is necessary to provide a gradual transition from a straight tangent direction section to a curved path section. If the transition curve is not provided tire wear on large jet transports can be excessive.
9. Sufficient distance must be provided to comfortably decelerate an aircraft after it leaves the runway. It is suggested that for the present this distance be based on an average rate of deceleration of 3.3 ft/s2. This applies only to transport category aircraft. Until more experience is gained with this type of operation the stopping distance should be measured from the edge of the runway.

Location of Exit Taxiways

The location of exit taxiways depends on the mix of aircraft, the approach and touchdown speeds, the point of touchdown, the exit speed, the rate of deceleration, which in turn depends on the condition of the pavement surface, that is, dry or wet, and the number of exits. While the rules for flying transport aircraft are relatively precise, a certain amount of variability among pilots is bound to occur especially in respect to braking force applied on the runway and the distance from runway threshold to touchdown. The rapidity and the manner in which air traffic control can process arrivals is an extremely important factor in establishing the location of exit taxiways. The location of exit taxiways is also influenced by the location of the runways relative to the terminal area.

Holding Aprons

Holding aprons, holding pads, run-up pads, or holding bays as they are sometimes called, are placed adjacent to the ends of runways. The areas are used as storage areas for aircraft prior to takeoff. They are designed so that one aircraft can bypass another whenever this is necessary. For piston-engine aircraft the holding apron is an area where the aircraft instrument and engine operation can be checked prior to takeoff. The holding apron also provides for a trailing aircraft to bypass a leading aircraft in case the takeoff clearance of the latter must be delayed for one reason or another, or if it experiences some malfunction. There are many configurations of holding aprons. The important design criteria are to provide adequate space for aircraft to maneuver easily onto the runway irrespective of the position of adjacent aircraft on the holding apron and to provide sufficient room for an aircraft to bypass parked aircraft on the holding apron. The recommendations for the minimum separation between aircraft on holding aprons are the same as those specified for the taxiway object-free area.

Holding pads must be designed for the largest aircraft which will use the pad. The holding pad should be located so that all aircraft using the pad will be located outside both the runway and taxiway object-free area and in a position so as not to interfere with critical ILS signals.

Lecture-40

AIRPORT LAYOUTS AND TERMINAL BUILDING

Terminal building

The terminal area is the major interface between the airfield and the rest of the airport. It includes the facilities for passenger and baggage processing, cargo handling, and airport maintenance, operations, and administration activities. The passenger processing system is discussed at length in this chapter. Baggage processing, cargo handling, and apron requirements are also discussed relative to the terminal system.

The Passenger Terminal System

The passenger terminal system is the major connection between the ground access system and the aircraft. The purpose of this system is to provide the interface between the passenger airport access mode, to process the passenger for origination, termination, or continuation of an air transportation trip, and convey the passenger and baggage to and from the aircraft.

Components of the System

The passenger terminal system is composed of three major components. These components and the activities that occur within them are as follows:

1. The access interface where the passenger transfers from the access mode of travel to the passenger processing component. Circulation, parking, and curbside loading and unloading of passengers are the activities that take place within this component.
2. The processing component where the passenger is processed in preparation for starting, ending, or continuation of an air transportation trip. The primary activities that take place within this component are ticketing, baggage check-in, baggage claim, seat assignment, federal inspection services, and security.
3. The flight interface where the passenger transfers from the processing component to the aircraft. The activities that occur here include assembly, conveyance to and from the aircraft, and aircraft loading and unloading.

A number of facilities are provided to perform the functions of the passenger terminal system. These facilities are indicated for each of the components identified above.

The Access Interface

This component consists of the terminal curbs, parking facilities, and connecting roadways that enable originating and terminating passengers, visitors, and baggage to enter and exit the terminal. It includes the following facilities:

1. The enplaning and deplaning curb frontage which provide the public with loading and unloading for vehicular access to and from the terminal building

2. The automobile parking facilities providing short-term and long-term parking spaces for passengers and visitors, and facilities for rental cars, public transit, taxis, and limousine services

3. The vehicular roadways providing access to the terminal curbs,

parking spaces, and the public street and highway system 4. The designated pedestrian walkways for crossing roads including tunnels, bridges, and automated devices which provide access between the parking facilities and the terminal building

5. The service roads and fire lanes which provide access to various facilities in the terminal and to other airport facilities, such as air freight, fuel truck stands, and maintenance.

The ground access system at an airport is a complex system of roadways, parking facilities, and terminal access curb fronts. This complexity is illustrated in Fig. 10-1 which shows the various ground access system facilities and directional flows at Greater Pittsburgh International Airport.

The Processing System

The terminal is used to process passengers and baggage for the interface with aircraft and the ground transportation modes. It includes the following facilities:

1. The airline ticket counters and offices used for ticket transactions, baggage check-in, flight information, and administrative personnel and facilities

2. The terminal services space which consists of the public and nonpublic areas such as concessions, amenities for passengers and visitors, truck service docks, food preparation areas, and food and miscellaneous storage

3. The lobby for circulation and passenger and visitor waiting 4. Public circulation space for the general circulation of passengers and visitors consisting of such areas as stairways, escalators, elevators, and corridors

5. The outbound baggage space which is a nonpublic area for sorting and processing baggage for departing flights

6. The intraline and interline baggage space used for processing baggage transferred from one flight to another on the same or different airlines
7. The inbound baggage space which is used for receiving baggage from an arriving flight, and for delivering baggage to be claimed by the arriving passenger
8. Airport administration and service areas used for airport management, operations, and maintenance facilities
9. The federal inspection service facilities which are the areas for processing passengers arriving on international flights, as well as performing agricultural inspections, and security functions.

Lecture-41

AIRPORT MAKING AND LIGHTING-I

Introduction

Visual aids assist the pilot on approach to an airport, as well as navigating around an airfield and are essential elements of airport infrastructure. As such, these facilities require proper planning and precise design.

These facilities may be divided into three categories: lighting, marking, and signage. Lighting is further categorized as either approach lighting or surface lighting. Specific lighting systems described in this chapter include

1. Approach lighting
2. Runway threshold lighting
3. Runway edge lighting
4. Runway centerline and touchdown zone lights
5. Runway approach slope indicators
6. Taxiway edge and centerline lighting

The proper placement of these systems is described in this chapter but no attempt has been made to describe in detail the hardware or its installation. Airfield marking and signage includes

1. Runway and taxiway pavement markings
2. Runway and taxiway guidance sign systems

Airfield lighting, marking, and signage facilities provide the following functions:

1. Ground to air visual information required during landing
2. The visual requirements for takeoff and landing
3. The visual guidance for taxiing

[*] Under revision

The Requirements for Visual Aids

Since the earliest days of flying, pilots have used ground references for navigation when approaching an airport, just as officers on ships at sea have used landmarks on shore when approaching a harbor. Pilots need visual aids in good weather as well as in bad weather and during the day as well as at night.

In the daytime there is adequate light from the sun, so artificial lighting is not usually required but it is necessary to have adequate contrast in the field of view and to have a suitable pattern of brightness so that the important features of the airport can be identified and oriented with respect to the position of the aircraft in space. These requirements are almost automatically met during the day when the weather is clear.

The runway for conventional aircraft always appears as a long narrow strip with straight sides and is free of obstacles. It can therefore be easily identified from a distance or by flying over the field. Therefore, the perspective view of the runway and other identifying reference landmarks are used by pilots as visual aids for orientation when they are approaching the airport to land. Experience has demonstrated that the horizon, the runway edges, the runway threshold, and the centreline of the runway are the most important elements for pilots to see.

In order to enhance the visual information during the day, the runway is painted with standard marking patterns. The key elements in these patterns are the threshold, the centerline, the edges, plus multiple parallel lines to increase the perspective and to define the plane of the surface.

During the day when visibility is poor and at night, the visual information is reduced by a significant amount over the clear weather daytime scene. It is therefore essential to provide visual aids which will be as meaningful to pilots as possible.

The Airport Beacon

Beacons are lighted to mark an airport. They are designed to produce a narrow horizontal and vertical beam of high-intensity light which is rotated about a vertical axis so as to produce approximately 12 flashes per minute for civil airports and 18 flashes per minute for military airports. The flashes with a clearly visible duration of at least 0.15 s are arranged in a white-green sequence for land airports and a white yellow sequence for landing areas on water. Military airports use a double white flash followed by a longer green or yellow flash to

[*] Under revision

differentiate them from civil airfields. The beacons are mounted on top of the control tower or similar high structure in the immediate vicinity of the airport.

Obstruction Lighting

Obstructions are identified by fixed, flashing, or rotating red lights or beacons. All structures that constitute a hazard to aircraft in flight or during landing or takeoff are marked by obstruction lights having a horizontally uniform intensity duration and a vertical distribution design to give maximum range at the lower angles (1.5° to 8°) from which a colliding approach would most likely come.

The Aircraft Landing Operation

An aircraft approaching a runway in a landing operation may be visualized as a sequence of operations involving a transient body suspended in a three-dimensional grid that is approaching a fixed two-dimensional grid. While in the air, the aircraft can be considered as a point mass in a three-dimensional orthogonal coordinate system in which it may have translation along three coordinate directions and rotation about three axes. If the three coordinate axes are aligned horizontal, vertical, and parallel to the end of the runway, the directions of motion can be described as lateral, vertical, and forward. The rotations are normally called pitch, yaw, and roll, for the horizontal, vertical, and parallel axes, respectively. During a landing operation, pilots must control and coordinate all six degrees of freedom of the aircraft so as to bring the aircraft into coincidence with the desired approach or reference path to the touchdown point on the runway. In order to do this, pilots need translation information regarding the aircraft‘s alignment, height, and distance, rotation information regarding pitch, yaw, and roll, and information concerning the rate of descent and the rate of closure with the desired path.

Alignment Guidance

Pilots must know where their aircraft is with respect to lateral displacement from the centerline of the runway. Most runways are from 75 to 200 ft wide and from 3000 to 12,000 ft long. Thus any runway is a long narrow ribbon when first seen from several thousand feet above. The predominant alignment guidance comes from longitudinal lines that constitute the centerline and edges of the runway. All techniques, such as painting, lighting, or surface treatment that develop contrast and emphasize these linear elements are helpful in providing alignment information.

Height Information

The estimation of the height above ground from visual cues is one of the most difficult judgments for pilots. It is simply not possible to provide good height information from an approach lighting system. Consequently the best source of height information is the instrumentation in the aircraft. However, use of these instruments often requires the availability of precision ground or satellite based navigation technologies.

Approach Lighting

Approach lighting systems (ALS) are designed specifically to provide guidance for aircraft approaching a particular runway under night time or other low-visibility conditions. While under night time conditions it may be possible to view approach lighting systems from several miles away, under other low-visibility conditions, such as fog, even the most intense ALS systems may only be visible from as little as 2500 ft from the runway threshold.

Studies of the visibility in fog have shown that for a visual range of 2000 to 2500 ft it would be desirable to have as much as 200,000 candelas (cd) available in the outermost approach lights where the slant range is relatively long. Under these same conditions the optimum intensity of the approach lights near the threshold should be on the order of 100 to 500 cd. A transition in the intensity of the light that is directed toward the pilot is highly desirable in order to provide the best visibility at the greatest possible range and to avoid glare and the loss of contrast sensitivity and visual acuity at short range.

System Configurations

The configurations which have been adopted are the Calvert system shown in Fig. ‗a' which has been widely used in Europe and other parts of the world, the ICAO category II and category III system shown in Fig. ‗b', and the four system configurations which have been adopted by the FAA in the United States. The FAA publishes criteria for the establishment of the approach lighting systems and other navigation facilities at airports. Approach lights are normally mounted on frangible pedestals of varying height to improve the perspective of the pilot in approaching a runway.

MALSR system.

At smaller airports where precision approaches are not required, a medium ALS with sequential flashers (MALSF) or with sequenced flashers (MALS) is adequate. The system is only 1400 ft long compared to a length of 2400 ft for a precision approach system. It is therefore much more economical, an important factor at small airports. The runway alignment indicator lights and these are only provided in the outermost 400 ft of the 1400-ft system to improve pilot recognition of the runway approach in areas where there are distracting lights in the vicinity of the airport. The MALS system does not have the runway alignment indicator lights or the sequential flashers. At international airports in the United States, the 2400-ft ALSs are often extended to a distance of 3000 ft to conform to international specifications.

Sequenced-flashing high-intensity lights are available for airport use and are installed as supplements to the standard approach lighting system at those airports where very low visibilities occur frequently.

These lights operate from the stored energy in a capacitor which is discharged through the lamp in approximately 5 ms and may develop as much as 30 million cd of light. They are mounted in the same pedestals as the light bars. The lights are sequence-fired, beginning with the unit farthest from the runway. The complete cycle is repeated every 2s. This results in a brilliant ball of light continuously moving toward the runway.

Since the very bright light can interfere with the eye adaptation of the pilot, condenser discharge lamps are usually omitted in the 1000 ft of the approach lighting system nearest the runway.

Visual Approach Slope Aids

Visual approach slope aids are lighting systems designed to provide a measure of vertical guidance to aircraft approaching a particular runway. The principle of these aids is to provide color-based identification to the pilot indicating their variation from a desired altitude and descent rate while on approach. The two most common visual approach slope aids are the visual approach slope indicator (VASI), and the precision approach path indicator (PAPI).

Visual Approach Slope Indicator

The visual approach slope indicator (VASI) is a system of lights which acts as an aid in defining the desired glide path in relatively good weather conditions. VASI lighting intensities are designed to be visible from 3 to 5 mi during the day and up to 20 mi at night. There are a number of different VASI configurations depending on the desired visual range, the type of aircraft, and whether large wide bodied aircraft will be using the runway. Each group of lights transverse to the direction of the runway is referred to as a *bar*. The downwind bar is typically located between 125 and 800 ft from the runway threshold, each subsequent bar is located between 500 and 1000 ft from the previous bar. A bar is made up of one, two, or three light units, referred to as *boxes*. The basic VASI-2 system, is a two-bar system consisting of four boxes. The bar that is nearest to the runway threshold is referred to as the *downwind bar*, and the bar that is farthest from the runway threshold is referred to as the *upwind bar*. If pilots are on the proper glide path, the downwind bar appears white and the upwind bar appears red; if pilots are too low, both bars appear red; and if they are too high both bars appear white.

In order to accommodate large wide bodied aircraft where the height of the eye of the pilot is much greater than in smaller jets, a third upwind bar is added. For wide bodied aircraft the middle bar becomes the downwind bar and the third bar is the upwind bar. In other words, pilots of large wide bodied aircraft ignore the bar closest to the runway threshold and use the other two bars for visual reference..

The more common systems in use in the United States are the VASI-2, VASI-4, VASI-12, and VASI-16. VASI systems are particularly useful on runways that do not have an instrument landing system or for aircraft not equipped to use an instrument landing system.

Precision Approach Path Indicator

The FAA presently prefers the use of another type of visual approach indicator called the *precision approach path indicator* (PAPI) [20]. This system gives more precise indications to the pilot of the approach path of the aircraft and utilizes only one bar as opposed to the minimum of two required by the VASI system. The system consists of a unit with four lights on either side of the approach runway.

Threshold Lighting

During the final approach for landing, pilots must make a decision to complete the landing or ‒execute a missed approach.‖ The identification of the threshold is a major factor in pilot decisions to land or not to land. For this reason, the region near the threshold is given special lighting consideration. The threshold is identified at large airports by a complete line of green lights extending across the entire width of the runway, and at small airports by four green lights on each side of the threshold. The lights on either side of the runway threshold may be elevated.

Threshold lights in the direction of landing are green but in the opposite direction these lights are red to indicate the end of the runway.

Runway Lighting

After crossing the threshold, pilots must complete a touchdown and roll out on the runway. The runway visual aids for this phase of landing are be designed to give pilots information on alignment, lateral displacement, roll, and distance. The lights are arranged to form a visual pattern that pilots can easily interpret.

At first, night landings were made by floodlighting the general area. Various types of lighting devices were used, including automobile headlights, arc lights, and search lights. Boundary lights were added to outline the field and to mark hazards such as ditches and fences. Gradually, preferred landing directions were developed, and special lights were used to indicate these directions. Floodlighting was then restricted to the preferred landing directions, and runway edge lights were added along the landing strips. As experience was developed, the runway edge lights were adopted as visual aids on a runway. This was followed by the use of runway center line and touchdown zone lights for operations in very poor visibility. FAA Advisory Circular 150/5340-30C provides guidance for the design and installation of runway and taxiway lighting systems.

Runway Edge Lights

Runway edge lighting systems outline the edge of runways during night time and reduced visibility conditions. Runway edge lights are classified by intensity, high intensity (HIRL), medium intensity (MIRL), and low intensity (LIRL). LIRLs are typically installed on visual runways and at rural airports. MIRLs are typically installed on visual runways at larger airports and on non-precision instrument runways, HIRLs are installed on precision-instrument runways. Elevated runway lights are mounted on frangible fittings and project no more than 30 in above the surface on which they are installed. They are located along the edge of the runway not more than 10 ft from the edge of the full-strength pavement surface. The longitudinal spacing is not more than 200 ft. Runway edge lights are white, except that the last 2000 ft of an instrument runway in the direction of aircraft operations these lights are yellow to indicate a caution zone.

Runway Center line and Touchdown Zone Lights

As an aircraft traverses over the approach lights, pilots are looking at relatively bright light sources on the extended runway center line. Over the runway threshold, pilots continue to look along the center line, but the principal source of guidance, namely, the runway edge lights, has moved far to each side in their peripheral vision. The result is that the central area appears excessively black, and pilots are virtually flying blind, except for the peripheral reference information, and any reflection of the runway pavement from the aircraft‘s landing lights. Attempts to eliminate this ―black hole‖ by increasing the intensity of runway edge lights have proven ineffective. In order to reduce the black hole effect and provide adequate guidance during very poor visibility conditions, runway center line and touchdown zone lights are typically installed in the pavement.

Runway End Identifier Lights

Runway end identifier lights (REIL) are installed at airports where there are no approach lights to provide pilots with positive visual identification of the approach end of the runway. The system consists of a pair of synchronized white flashing lights located on each side of the runway threshold and is intended for use when there is adequate visibility.

Lecture-42

AIRPORT MAKING AND LIGHTING-II

Taxiway Lighting

Either after a landing or on the way to takeoff, pilots must maneuver the aircraft on the ground on a system of taxiways to and from the terminal and hangar areas. Taxiway lighting systems are provided for taxiing at night and also during the day when visibility is very poor, particularly at commercial service airports. The following overall guidance should be applied in determining the lighting, marking, and signing visual aid requirements for taxiways:

- In order to avoid confusion with runways, taxiways must be clearly identified.
- Runway exits need to be readily identified. This is particularly true for high-speed runway exits so that pilots can be able to locate these exits 1200 to 1500 ft before the turnoff point.
- Adequate visual guidance along the taxiway must be provided.
- Specific taxiways must be readily identified.
- The intersections between taxiways, the intersections between runways and taxiways, and runway-taxiway crossings need to be clearly marked.
- The complete taxiway route from the runway to the apron and from the apron to the runway should be easily identified. There are two primary types of lights used for the designation of taxiways. One type delineates the edges of taxiways and the other type delineates the center line of the taxiway.

Taxiway Edge Lights

Taxiway edge lights are elevated blue colored bidirectional lights usually located at intervals of not more than 200 ft on either side of the taxiway. The exact spacing is influenced by the physical layout of the taxiways. Straight sections of taxiways generally require edge light spacing in 200-ft intervals, or at least three lights equally spaced for taxiway straight line sections less than 200 ft in length.

Closer spacing is required on curves. Light fixtures are located not more than 10 ft from the edge of full strength pavement surfaces. Taxiway centerline lights are in-pavement bidirectional lights placed in equal intervals over taxiway centerline markings. Taxiway centreline lights are green, except in areas where the taxiway intersects with a runway, where the green and yellow lights are placed alternatively.

Research and experience have demonstrated that guidance from centerline lights is superior to that from edge lights, particularly in low visibility conditions.

For normal exits, the centerline lights are terminated at the edge of the runway. At taxiway intersections the lights continue across the intersection. For long-radius high-speed exit taxiways, the taxiway lights are extended onto the runway from a point 200 ft back from the point of curvature (PC) of the taxiway to the point of tangency of the central curve of the taxiway. Within these limits the spacing of lights is 50 ft. These lights are offset 2 ft from the runway centerline lights and are gradually brought into alignment with the centerline of the taxiway. Where the taxiways intersect with runways and aircraft are required to hold short of the runway, several yellow lights spaced at 5-ft intervals are placed transversely across the taxiway.

Runway Guard Lights

Runway guard lights (RGLs) are in-pavement lights located on taxiways at intersections of runways to alert pilots and operators of airfield ground vehicles that they are about to enter onto an active runway. RGLs are located across the width of the taxiway, approximately 2 ft from the entrance to a runway, spaced at approximately 10-ft intervals,

Runway Stop Bar

Similar to runway guard lights, runway stop bar lights are in-pavement lights on taxiways at intersections with runways. As opposed to RGLs that provide warning to pilots approaching a runway, runway stop bar lights are designed to act as ―stop‖ lights, directing aircraft and vehicles on the taxiway not to enter the runway environment. Runway stop bar lights are activated with red illuminations during periods of runway occupancy or other instances where entrance from the taxiway to the runway is prohibited. In-pavement runway stop bar lighting is typically installed in conjunction with elevated runway guard lights located outside the width of the pavement.

Runway and Taxiway Marking

In order to aid pilots in guiding the aircraft on runways and taxiways, pavements are marked with lines and numbers. These markings are of benefit primarily during the day and dusk. At night, lights are used to guide pilots in landing and maneuvering at the airport. White is used for all markings on runways and yellow is used on taxiways and aprons.

Runways

The FAA has grouped runways for marking purposes into three classes:

(1) Visual, or –basic‖ runways,

(2) Nonprecision instrument runways, and

(3) Precision instrument runways.

The visual runway is a runway with no straight-in instrument approach procedure and is intended solely for the operation of aircraft using visual approach procedures. The nonprecision instrument runway is one having an existing instrument approach procedure utilizing air navigation facilities with only horizontal guidance (typically VOR or GPS-based RNAV approaches without vertical guidance) for which a straight-in nonprecision approach procedure has been approved. A precision instrument runway is one having an existing instrument approach procedure utilizing a precision instrument landing system or approved GPS-based RNAV (area navigation) or RNP (required navigation performance) precision approach. Runways that have a published approach based solely on GPS-based technologies are known as GPS runways.

Runway markings include runway designators, center lines, threshold markings, aiming points, touchdown zone markings, and side stripes. Depending on the length and class of runway and the type of aircraft operations intended for use on the runway, all or some of the above markings are required.

Runway Designators

The end of each runway is marked with a number, known as a runway designator, which indicates the approximate magnetic azimuth (clockwise from magnetic north) of the runway in the direction of operations. The marking is given to the nearest 10° with the last digit omitted. Thus a runway in the direction of an azimuth of 163° would be marked as runway 16 and this runway would be in the approximate direction of south-south-east. Therefore, the east end of an east-west runway would be marked 27 (for 270° azimuth) and the west end of an east-west runway would be marked 9 (for a 90° azimuth). If there are two parallel runways in the east-west direction, for example, these runways would be given the designation 9L-27R and 9R-27L to indicate the direction of each runway and their position (L for left and R for right) relative to each other in the direction of aircraft operations. If a third parallel runway existed in this situation it has traditionally been given the designation 9C-27C to indicate its direction and position relative (C for center) to the other runways in the direction of aircraft operations.

Runway Threshold Markings

Runway threshold markings identify to the pilot the beginning of the runway that is safe and available for landing. Runway threshold markings begin 20 ft from the runway threshold itself. Runway threshold markings consist of two series of white stripes, each stripe 150 ft in length and 5.75 ft in width, separated about the centerline of the runway. On each side of the runway centerline, a number of threshold marking stripes are placed, For example, for a 100-ft runway, eight stripes are required, in two groups of four are placed about the centerline. Stripes within each set are separated by 5.75 ft. Each set of stripes is separated by 11.5 ft about the runway centerline.

Centerline Markings

Runway centerline markings are white, located on the centerline of the runway, and consist of a line of uniformly spaced stripes and gaps. The stripes are 120 ft long and the gaps are 80 ft long. Adjustments to the lengths of stripes and gaps, where necessary to accommodate runway length, are made near the runway midpoint. The minimum width of stripes is 12 in for visual runways, 18 in for nonprecision instrument runways, and 36 in for precision instrument runways. The purpose of the runway centerline markings is to indicate to the pilot the center of the runway and to provide alignment guidance on landing and takeoff.

Aiming Points

Aiming points are placed on runways of at least 4000 ft in length to provide enhanced visual guidance for landing aircraft. Aiming point markings consist of two bold stripes, 150 ft long, 30 ft wide, spaced 72 ft apart symmetrically about the runway centerline, and beginning 1020 ft from the threshold.

Touchdown Zone Markings

Runway touchdown zone markings are white and consist of groups of one, two, and three rectangular bars symmetrically arranged in pairs about the runway centerline. These markings begin 500 ft from the runway threshold. The bars are 75 ft long, 6 ft wide, with 5 ft spaces between the bars, and are longitudinally spaced at distances of 500 ft along the runway. The inner stripes are placed 36 ft on either side of the runway centerline. For runways less than 150 ft in width, the width and spacing of stripes may be proportionally reduced. Where touchdown zone markings are installed on both runway ends on shorter runways, those pairs of markings which would extend to within 900 ft of the runway midpoint are eliminated.

Side Stripes

Runway side stripes consist of continuous white lines along each side of the runway to provide contrast with the surrounding terrain or to delineate the edges of the full strength pavement. The maximum distance between the outer edges of these markings is 200 ft and these markings have a minimum width of 3 ft for precision instrument runways and are at least as wide as the width of the centerline stripes on other runways.

Displaced Threshold Markings

At some airports it is desirable or necessary to ―displace‖ the runway threshold on a permanent basis. A displaced threshold is one which has been moved a certain distance from the end of the runway. Most often this is necessary to clear obstructions in the flight path on landing. The displacement reduces the length of the runway available for landings, but takeoffs can use the entire length of the runway.

These markings consist of arrows and arrow heads to identify the displaced threshold and a threshold bar to identify the beginning of the runway threshold itself. Displaced threshold arrows are 120 ft in length, separated longitudinally by 80 ft for the length of the displaced threshold. Arrow heads are 45 ft in length, placed 5 ft from the threshold bar. The threshold bar is 5 ft in width and extends the width of the runway at the threshold.

Blast Pad Markings

In order to prevent erosion of the soil, many airports provide a paved *blast pad* 150 to 200 ft in length adjacent to the runway end. Similarly, some airport runways have a *stopway* which is only designed to support aircraft during rare aborted takeoffs or landing overruns and is not designed as a full strength pavement. Since these paved areas are not designed to support aircraft and yet may have the appearance of being so designed, markings are required to indicate this.

Centerline and Edge Markings

The centerline of the taxiway is marked with a single continuous 6-in yellow line. On taxiway curves, the taxiway centerline marking continues from the straight portion of the taxiway at a constant distance from the outside edge of the curve. At taxiway intersections which are designed for aircraft to travel straight through the intersection, the centerline markings continue straight through the intersection. At the intersection of a taxiway with a runway end, the centerline stripe of the taxiway terminates at the edge of the runway.

Taxiway Hold Markings

For taxiway intersections where there is an operational need to hold aircraft, a dashed yellow holding line is placed perpendicular to and across the centerline of both taxiways. When a taxiway intersects a runway or a taxiway enters an instrument landing system critical area, a holding line is placed across the taxiway. The holding line for a taxiway intersecting a runway consists of two solid lines of yellow stripes and two broken lines of yellow stripes placed perpendicular to the centerline of the taxiway and across the width of the taxiway. The solid lines are always placed on the side where the aircraft is to hold. The holding line for an instrument landing system critical area consists of two solid lines placed perpendicular to the taxiway centerline and across the width of the taxiway joined with three sets of two solid lines symmetrical about and parallel to the taxiway center line.

Taxiway Shoulders

In some areas on the airfield, the edges of taxiways may not be well defined due to their adjacency to other paved areas such as aprons and holding bays. In these areas, it is prudent to mark the edges of taxiways with shoulder markings. Taxiway shoulder markings are yellow in colour, and are often painted on top of a green background. The shoulder markings consist of 3-ft-long yellow stripes placed perpendicular to the taxiway edge stripes, On straight sections of the taxiway, the marks are placed at a maximum spacing of 100 ft. On curves, the marks are placed on a maximum of 50 ft apart between the curve tangents.

Enhanced Taxiway Markings

Beginning in 2008, all airports serving commercial air carriers are required to mark certain critical areas of the airfield with enhanced taxiway markings. These markings are designed to provide additional guidance and warning to pilots of runway intersections.

Enhanced markings consist primarily of yellow-painted lines, using paint mixtures with imbedded glass beads to enhance visibility. In addition, yellow markings must be marked on top of a darkened black background.

Taxiway centerlines are enhanced for 150 ft from the runway hold-short markings. The centerline enhancements include dashed yellow lines 9 ft in length, separated longitudinally by 3 ft. These yellow lines are placed 6 in from each end of the existing centerline.

Closed Runway and Taxiway Markings

When runways or taxiways are permanently or temporarily closed to aircraft, yellow crosses are placed on these trafficways. For permanently closed runways, the threshold, runway designation, and touchdown markings are obliterated and crosses are placed at each end and at 1000 ft intervals. For temporarily closed runways, the runway markings are not obliterated, the crosses are usually of a temporary type and are only placed at the runway ends. For permanently closed taxiways, a cross is placed on the closed taxiway at each entrance to the taxiway. For temporarily closed taxiways barricades with orange and white markings are normally erected at the entrances.

Lecture-43

INSTRUMENTAL LANDING SYSTEMS AND AIR NAVIGATION AIDS

Aids to navigation, known as NAVAIDS, can be broadly classified into two groups, ground-based systems and satellite-based systems. Each system is complimented by systems installed in the cockpit.

Ground-Based Systems

Non directional Beacon

The oldest active ground-based navigational aid is the nondirectional beacon (NDB). The NDB emits radio frequency signals on frequencies between 400 and 1020 Hz modulation. NDBs are typically mounted on a pole approximately 35 ft tall. They may be located on or off airport property, at least 100 ft clear of metal buildings, power lines, or metal fences. While the NDB is quickly being phased out in the United States, it is still a very common piece of navigational equipment in other parts of the world, particularly in developing nations. Figure 3-8 provides an illustration of an NDB.

Aircraft navigate using the NDB by referencing an automatic direction finder (ADF) located on the aircraft‘s panel. The ADF simply points toward the location of the NDB. Figure 3-9 illustrates an ADF system.

Very High Frequency Omnirange Radio

The advances in radio and electronics during and after World War II led to the installation of the very high frequency omnirange (VOR) radio stations. These stations are located on the ground and send out radio signals in all directions. Each signal can be considered as a course or a route, referred to as a radial that can be followed by a aircraft. In terms of 1° intervals, there are 360 courses or routes that are radiated from a VOR station, from 0° pointing toward magnetic north increasing to 359° in a clockwise direction. The VOR transmitter station is a small square building topped with what appears to be a white derby hat. It broadcasts on a frequency just above that of FM radio stations. The very high frequencies it uses are virtually free of static. The system of VOR stations establish the network of airways and jet routes and are also essential to area navigation. The range of a VOR station varies but is usually less than 200 nm. A typical VOR beacon is illustrated in Fig. 3-10.

Aircraft equipped with a VOR receiver in the cockpit have a dial for tuning in the desired VOR frequency. A pilot can select the VOR radial or route he wishes to follow to the VOR station. In the cockpit there is also an omnibearing selector (OBS) which indicates the heading of the aircraft relative to the direction of the desired radial and whether the aircraft is to the right or left of the radial. An illustration of an OBS is provided in Fig. 3-11.

Distance Measuring Equipment

Distance measuring equipment (DME) has traditionally been installed at VOR stations in the United States. The DME shows the pilot the slant distance between the aircraft and a particular VOR station. Since it is the air distance in nautical miles that is measured, the receiving equipment in an aircraft flying at 35,000 ft directly over the DME station would read 5.8 nm.

An en route air navigation aid which best suited the tactical needs of the military was developed by the Navy in the early 1950s. This aid is known as TACAN, which stands for tactical air navigation. This aid combines azimuth and distance measuring into one unit instead of two and is operated in the ultra-high-frequency band. As a compromise between civilian and military requirements, the FAA replaced the DME portion of its VOR facilities with the distance measuring components of TACAN. These stations are known as VORTAC stations. If a station has full TACAN equipment, both azimuth and distance measuring equipment, and also VOR, it is designated as VORTAC.

NDB and VOR systems are often located on airport airfields. The location of these systems on airport, known as TVORs, are significant to airport planners and designers, as the location of other facilities, such as large buildings, particularly constructed of metal, may adversely affect the performance of the navaid.

As illustrated in Fig. 3-12, TVORs should be located at least 500 ft from any runways and 250 ft from any taxiways. Any structures or trees should be located at least 1000 ft from the TVOR antenna. There should also be a clearance angle of at least 2.5° for any structures and 2.0° for any trees beyond 1000 ft, as illustrated in Fig. 3-13.

Airport traffic control

Air traffic control facility provide the basis for communication with aircraft and the relay and clearance of flight plans for air traffic. There are three basic types of facilities: air route traffic control centre, airport traffic control tower and flight service station. The first attempt to set up rules for air traffic control was made by the International Commission for Air Navigation (ICAN), which was under the direction of the League of Nations. The procedures which the commission promulgated in July of 1922 were adopted by 14 countries. Although the United States was not a member of the League of Nations, and therefore did not officially adopt the rules, many of the procedures established by ICAN were used in the promulgation of air traffic procedures in the United States as well as in most regions of the world. Construction and operation of the airways system in the United States prior to 1926 were controlled by the military and by the Post Office Department. The formal entry of the federal government into the regulation of air traffic came with the passage of the Air Commerce Act of 1926 (Public Law 64-254). This act directed the Bureau of Air Commerce to establish, maintain, and operate lighted civil airways. At the present time the Federal Aviation Administration maintains and operates the airways system of the United States.

Air route traffic control centre (ARTCC)

There are several domestic air route traffic control the movement of aircraft along the airways. Each centre has control of a definite geographical area and is concern primarily with the control of aircraft. At the boundary limit of the control area of the centre, aircraft is released either to adjacent centre or to an airport control tower. Nowadays most of the aircraft separation is maintained by radar. Each ARTCC is broken down into sectors in order to increase efficiency of the personnel in the centre. Each sector are smaller geographical areas, air traffic is monitored in each sector by remote radar unit at the geographical location. In the process aircraft flight plan is transferred between the sectors within an air route traffic control centre and between the air tarfic control centre when crossing the ARTCC boundary.

Airport traffic control tower

Airport control towers are the facilities that supervise, direct and monitor traffic within the airport area. The control tower provides a traffic control function for aircraft arriving or departing from an airport for 5 to 20km radius.

Some control tower have approach control facilities and associated airport surveillance radar (ASR) which guide aircraft to the airport from a number of specific positions, called ―fixes‖ within approximately 40 km of airport. Aircraft are brought to this position by ARTCCs. It is often at these fixes; aircraft are held or ―stacked‖ for landing during periods of heavy traffic.

Flight service station (FSS)

FSS which are nowadays fully automated, are located long the airways and at airports. Thir main functions are

- Relay traffic control messages between en route aircraft and air route traffic control centre.
- Brief pilots, before flight and in flight, on weather, navigational aids, airports that are out of commission, and changes in procedure and new facilities.
- Disseminate weather information.
- Monitor navigation aids.

Bibliography

Chandra, S. (2008). *Railway engineering*. Oxford University Press, Inc..

Khanna, S. K., & Arora, M. G. (1971). *Airport Planning and Design*. Mom Chand.

[*] Under revision