**MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE**
**National Aviation University**
**Airport Institute**
**Computer technologies of construction department**

**O.V. RODCHENKO, V.YU. GYRYCH**

# AIRPORT DESIGN

## Lecture course

**Kyiv 2011**

УДК 625.717:725.398(042.4)
ББК О513.0-082я7
R69

Reviewed by: I.P. Hamelyak, Doctor of Science (Engineering), Professor of airport department of the National Transport University;

M.S. Barabash, Candidate of Science (Engineering), Associate Professor of computer technologies of construction department of National Aviation University;

N.I. Belov, chief of scientific and technical department of the Ukrainian State Designing Technological and Scientific Research Institute of Civil Aviation "Ukraeroproekt".

English adviser: L.V. Budko

Approved by the Methodical and Editorial Board of National Aviation University (Minutes № _______ of _________).

**Rodchenko O.V., Gyrych V.Yu.**
R69 **Airport Design**: lecture course / O.V. Rodchenko, V.Yu. Gyrych. – K.: NAU, 2011. – 112 p.

This lecture course contains theoretical fundamentals of airport master plan, air passenger and air freight terminals, airfield pavement design.

It is intended for the students of specialty 6.092101 “Industrial and Civil Engineering”.

**Родченко О.В., Гирич В.Ю.**
**Проектування аеропортів**: курс лекцій / О.В. Родченко, В.Ю. Гирич. – К.: НАУ, 2011. – 112 с.

Курс лекцій містить теоретичні основи проектування генерального плану аеропорту, пасажирських та вантажних терміналів, аеродромних покриттів.

Для студентів спеціальності 6.060101 „Промислове та цивільне будівництво”.

## CONTENTS

## PREFACE

This lecture course is titled "Airport Design". A poor design affects the airport operation and results in increasing costs. On the other hand it is difficult to design the airport infrastructure without profound knowledge of the airport operation. This is emphasized through the lectures.

This course does not offer a set of simple instructions for solving particular problems. Every airport is unique and a simple generic solution does not exist. Some of the differences that relate to the political and economic situations in Eastern and Western Europe are reflected here. The lecture course explains principles and relationships which are important for the construction of airport facilities, for airport management and for the safe and efficient control of operations.

We hope that we have been able to overcome the traditional view that an airport is only the runway and tarmac. An airport is a complex system of facilities and often the most important enterprise of a region. However, this lecture course is focused on specific part of the airport problem, namely design and operation, while bearing the other aspects in mind.

This edition includes some important changes in the international regulations covering airport engineering. It reflects the greater attention to security, safety and the environment, together with changes in the technology and the way the air transport industry operates.

# INTRODUCTION

Airports are the essential part of the air transport system. They provide the infrastructure needed to service passengers and freight, landing and takeoff of aircraft. Airports bring together a wide range of facilities and services in order to be able to fulfill their role within the air transport industry. These services include air traffic control, security, fire protection and so on in the airfield. Handling facilities are provided so that passengers, their baggage, and freight can be successfully transferred between aircraft and terminals, and processed within the terminal. Airports also offer a wide variety of commercial facilities ranging from shops and restaurants to hotels, conference services and business parks.

We usually associate air travel with speed, adaptability, light, air, comfort, and service. Thus, airport should be well designed. It is the architect's and civil engineer's job to provide desire of passengers, comfort and luxury.

The apron needs to have the capability to park all aircrafts. Thus, its area is often approximately in five times more than area of the air passenger terminal.

A conventional freight terminal should be located as close to the passenger terminal as possible, commensurate with master planning indications to extend the facilities, and with geotechnical site constraints: earth-moving, drainage, utilities, etc. The freight terminal should be also as close to the runway as possible. The aircraft should be parked as near as possible to the freight terminal in order to reduce the amount of ground traffic movement. This is essential if loading bridges are used.

Airport pavements are constructed to provide adequate support for the loads imposed by airplanes and to produce firm, stable, smooth, all-year, all-weather surface. In order to satisfactorily fulfill these requirements, the pavement must be of such quality and thickness that it will not fail under the load imposed. In addition, it must possess sufficient inherent stability to withstand, without damage, the abrasive action of traffic, adverse weather conditions, and other deteriorating influences. To produce such pavements, it is required coordination of many factors of design, and inspection to assure the best possible combination of available materials and high standards of workmanship.

The aviation community has large investment in airport pavements. The major objective in the design of these pavements is to provide adequate load-carrying capacity and good ride quality necessary for the safe operation of aircraft under all weather conditions. Normal distresses in the pavement structure result in surface weathering, fatigue effects, and differential movement in the underlying subbase. In addition, faulty construction techniques, substandard materials, or poor workmanship can accelerate the pavement deterioration process. Consequently, airport pavements require routine maintenance, rehabilitation and upgrading.

"Airports present gateways of opportunity to migrant populations, escape to holiday-minded couples, familiarity to frequent- flying executives. For a world in motion they are home, which remind us that despite being inherently alienating (often their features resemble each other more closely than those of the cities beyond their Hiding doors), they are equally sources of connection. Their scattered confines link together a global village."

***Nasid Hajary***

# MODULE #1. AIRPORT MASTER PLANNING

## Lecture #1.1

## Development of Airports

Plan

1. History of airports development.
2. Perspectives of airports development.

**1.** First, consider the well-known question: 'Which came first?' In fact, the answer is clear. The aeroplane came first. When aviation was in its infancy, the aviator first constructed an aeroplane, and then began to search for a suitable 'airfield', where he could test the machine. The aerodrome parameters had to be selected on the basis of performance and geometrical characteristics of the aircraft. The aerodromes always had to adapt to the needs of the aircraft.

The first aeroplanes were light, with a tail wheel, and the engine power was usually low. A mowed meadow with good water drainage was sufficient as an aerodrome for those aeroplanes. In the majority of cases, the aerodrome was used to be square or circular without the runway being marked out.

Immediately after World War I in 1919-1920, the first air carriers opened regular air services between Paris and London, Amsterdam and London, Prague and Paris, among others. However, at that period no noticeable changes occurred in the airport equipment, or in the basic operating concept, other than some simple building for the processing of passengers and hangars for working on the aeroplanes. The main change in the physical characteristics of airfield was the runway length. The multiengine aircraft required the length to increase to approximately 1000 m. The increasing number of aircraft, and the training of the military pilots required more support facilities at airfields, such as hangars, workshops and barracks.

War does not benefit mankind but, for aviation, it has always meant a rapid step change in development. After World War II, there were unusually favourable conditions for the development of civil aviation and air transport. On one hand, there were damaged ground communications, while on the other hand, there were plenty of surplus former military aircraft.

The new aircraft required paved runways, partly because they were heavier and partly because regularity of service became more important. However, they were still relatively sensitive to the crosswind, despite having nose-wheel steering. Therefore, the big international airports adopted a complicated system of between three and six runways in different directions in order to provide sufficient operational usability from the entire runway system. The large number of runways often reduced the amount of land available for further development of the airport. One of the runways, most often the runway in the direction of the prevailing winds, was gradually equipped with airport visual aids, thus being regarded as the main runway. At the same time terminal facilities were constructed which, besides the services required for the processing of passengers and their baggage, provided also the first non–aeronautical services, such as restaurants, toilets, and duty free shops.

The next substantial change that significantly influenced the development of airports was the introduction of aircraft with jet propulsion. Jet aircraft required further extension of the runway, together with increases in its width and upgrading its strength. The operation of jet aeroplanes had an effect also upon other equipment and technical facilities of the airport. One of them was the fuel supply system.

Most recent changes in airports have not been provoked by new aircraft technology, but by political and economic developments. The airport situation in Europe has changed considerably since the 1960s.

The airport in the past was a ‘shop-window’ of the state, and together with the national flag carrier, also an instrument to enforce state policy.

The following important factors influenced the entire development of airports from 1975 to 1992: the threat of terrorism and a fear of unlawful acts; the privatisation of airports; the progressive deregulation of air transport; the increasing environmental impact around airports.

**2.** According to Boeing forecast, air traffic will double by 2020 and new runways will be needed at 60 of the world’s largest airports by 2025.  Both companies anticipate the fastest market growth in the Asia-Pacific (including China) region, but also in other evolving markets as Brazil, Russia and India.  In these countries the traffic will grow three times faster than in North America and in Europe.

About 44% of the aircraft will be centred on the ten largest airports (Table 1.1) [12].

Table 1.1. World airports ranking by total passengers – 2010 data

| Rank | Airport | Total Passengers (millions) | % Change on 2009 |
|---|---|---|---|
| 1 | Atlanta (ATL) | 85.9 | 2.8 |
| 2 | Chicago (ORD) | 76.5 | 1.3 |
| 3 | Heathrow (LHR) | 67.9 | 0.8 |
| 4 | Tokio (HND) | 63.3 | 1.6 |
| 5 | Los Angeles (LAX) | 61.5 | 1.3 |
| 6 | Dallas/Fort Worth (DFW) | 59.2 | -0.4 |
| 7 | Paris (CDG) | 53.8 | 5.0 |
| 8 | Frankfurt/Main (FRA) | 52.2 | 2.2 |
| 9 | Amsterdam (AMS) | 44.2 | 3.8 |
| 10 | Las Vegas (LAS) | 44.0 | 6.0 |

*Note: Total Passengers mean Arriving + departing passengers + direct transit passengers counted once.*

So, the increasing volumes of passengers and freight will continue making demands for the expansion of airport facilities.

## Lecture #1.2

## Airports Structure

Plan

1. Airports structure.
2. Functions of airport.

**1.** ***Airports*** are the essential part of the air transport system. They provide all the infrastructure needed to enable passengers and freight to transfer from surface to air modes of transport and to allow airlines to take off and land. The basic airport infrastructure consists of runways, taxiways, apron space, gates, passenger and freight terminals, and ground transport interchanges. Airports bring together a wide range of facilities and services in order to be able to fulfill their role within the air transport industry. These services include air traffic control, security, fire and rescue in the airfield. Handling facilities are provided so that passengers, their baggage, and freight can be successfully transferred between aircraft and terminals, and processed within the terminal. Airports also offer a wide variety of commercial facilities ranging from shops and restaurants to hotels, conference services and business parks.

As well as playing a crucial role within the air transport sector, airports have strategy importance to the regions they serve. In a number of countries they are increasingly becoming integrated within the overall transport system by establishing links to high-speed rail and key road networks. Airports can bring greater wealth, provide substantial employment opportunities and encourage economic development and can be a lifeline to isolated communities. However, they do have a very significant effect, both on the environment in which they are located and on the quality of life of residents living nearby.

As an integral part of the transportation infrastructure, airports are all about getting from here to there, a brief pause in a long journey. Fundamentally, an airport should be designed to move passengers, cargo, mail, aircraft, and surface transportation vehicles efficiently, expeditiously, and pleasantly – at least cost and with less hassle [1].

**2.** The essential functions which must be performed at an airport include passenger ticketing, baggage check and pickup, customs, immigration, security, boarding and rebounding, and in the case of cargo and mail, tendering or picking up with appropriate air cargo waybills and documentation. The airport should be well designed and well signed to enhance rather than hinder efficient traffic flows. In a sense, airports are little different in function from the railway terminals they replaced. At a rail station, a departing passenger needs to purchase a ticket and board a train from the appropriate platform. At an airport, a departing passenger needs to be ticketed, receive a boarding pass, check luggage, and board an aircraft at the appropriate gate. On international flights, the passenger will also pass through immigration and customs, at departure and/or an arrival. At arrival, a passenger needs to collect bags and exit the terminal. The departure functions are shown in fig.1.1 and the arrival ones are presented in fig. 1.2.

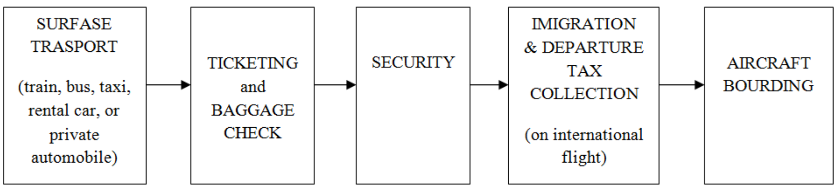



Fig. 1.1. Departure functions

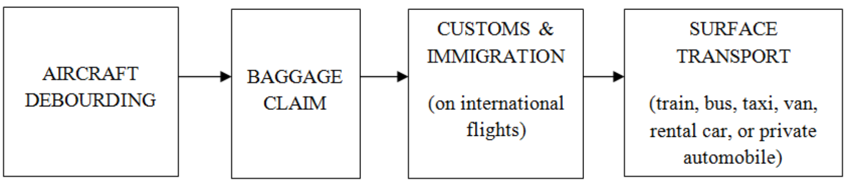



Fig. 1.2. Arrival functions

Airport building not only supply comfort, but also satisfies emotional and symbolic needs. We unconsciously associate air travel with speed, adaptability, light, air, comfort, and service. It is the architect's job to reinforce that unconscious desire, with the use of plenty of glass, muted colors, comfortable furniture, and perfect treatment of the passenger- the space surrounding the flowing movement should radiate not only an atmosphere of comfort and luxury, but also one of reassurance and mild euphoria [1, 10].

## Lecture #1.3

## Airport Master Plan

Plan

1. Notion about airport master plan.
2. Ten step sequence of airport master plan developing.

**1.** The ***Airport Master Plan*** may be characterized as: ‘a plan for the airport construction that considers the possibilities of maximum development of the airport in the given locality. The Master Plan of an airport may be elaborated for an existing airport as well as for an entirely new one, regardless of the size of the airport’. It is necessary to include not only the space of the airport itself and its facilities, but also other land and communities in its vicinity that are affected by the airport equipment and activities. The Airport Master Plan represents a guide as to how the airport development should be provided to meet the foreseen demand while maximizing and preserving the ultimate capacity of the site. Typically, ***the airport master plan document should be developed as a 30 year forecast of development options which would include the following topics:***

- long term phased objectives of airport development;
- concept variations (normally 3 or more suboptions developed);
- social and environmental impact statement and recommendations;
- runway development plan and recommendations;
- cost plan restraint objectives;
- construction programme constraints;
- energy consumption targets.

The Airport Master Plan should be used as a tool in the earlier stages of negotiations with the local planning authority to explain the level of impact the various options would have, and to help generate a forum for the authority's concerns as well as those of the local community. The airport master plan is created to guide the future development expectations of airports and to establish their ability to expand and is develop in a logical, sustainable and cost effective manner. Airline market forecast is discernibly linked to the master plan development proposal, i.e. as airport traffic increases the development of facility and operations should be phased to provide the appropriate airport processes and sized infrastructure.

Master plans should be systematically reviewed at least every 5 years. This regular review and update process should address variations in market forecast and the operational requirements of the airline clients.

The master plan will provide a detailed and accurate assessment of how an airport should deliver its services to its airline and ground handling clients in an effective and controlled manner, with due consideration for safety, development costs and the resultant realistic cost and profit recover mechanisms [9].

**2.** The following sequence should be followed when developing a master plan for a typical international or domestic airport passenger terminal and airport apron operation. Step 7 and step 10 should be exchanged in sequence when a predominantly cargo and express processing facility is proposed.

**Step 1.** Determine the peak aircraft movements and resulting peak passenger movements required in the final master plan design year.

**Step 2.** Collect via survey geographical, geological, meteorological and environmental data pertaining to the proposed airport site location.

**Step 3.** Select the runway configuration(s) which best matches the aircraft type and movement requirements, geological limitations and meteorological conditions, and which satisfies the environmental requirements as closely as possible.

**Step 4.** Align the proposed runway(s) to coincide with the prevailing wind directions.

**Step 5.** Determine and locate the number of aircraft stands required and the stand type (remote or gate serviced) needed to meet the service standard.

**Step 6.** Provide the correct configuration and quantity of taxiways, ensuring that the runways and stands are serviced adequately, with due consideration to the dynamics of the aircraft on the apron.

**Step 7.** Size and position the ultimate terminal buildings, piers and control tower within the appropriate development zones. The space requirement for the terminal building will be heavily dependent on the processes required.

**Step 8.** Align the ultimate terminal building and piers to service the aircraft stands accordingly. Position fire services within the apron complex appropriately.

**Step 9.** Size and position airport support processes such as (but not limited to rail, bus, coach and passenger car access and parking facilities.

**Step10.** Position secondary Cargo and Separate Express Facilities Terminal and stands, aircraft maintenance hangars as required within the surplus development zones [9].

## Lecture #1.4

## General Information about Airfield

Plan

1. Airfield configuration.
2. Runway capacity.
3. Runway elements.

**1.** The airport authority and the airport planning team must have comprehensive understanding of the airfield configuration options that exist. There are essentially six airfield configurations for airport planners to choose from Table 1.2. These all have various operational advantages and disadvantages and it should be noted that while six airfield configurations exist, only four are recommended by IATA for green-field or blue-sea situations.

Airfield configurations are determined by the number, position and orientation of existing and proposed runways and their support taxiway networks. This factor will greatly influence the position of all other primary and secondary support facilities [10].

**2.** Runway capacity is fundamentally driven by several factors, they are defined as follows:

**1. Aircraft type and mix** influence aircraft spacing on final approach or departure where wake vortices occur, as well as runway occupancy time, where aircraft weight and stopping distances are important factors.

**2. Runway design** includes the length available, access to taxiways for entry and exit from runways, the availability of high speed exits and entrances, etc.

**3. Aerodrome design** considers the support infrastructure, including terminal design and access to gates, and taxiway design, which can influence the ability to get to or from a runway, or to change runways when weather or other conditions require. This factor also includes access to precision landing or departure guidance, runway and taxiway lighting, etc.

**4. Engineered Runway Capacity** is the number of movements (landings and/or departures) that can be expected to occur on a particular runway, or set of runways, assuming that there are no physical or practical constraints to accessing the runway(s). This means that aircraft are able to vacate a runway at a stopping point, or roll directly onto a runway without stopping. It does, however, factor the predicted wake vortex spacing for a known or assumed traffic mix.

**5. Operational Runway Capacity** is the maximum number of movements that a runway can achieve and sustain in normal operating conditions [10].

Table 1.2. Runway Configuration Assessment

| Runway Configuration | Runway Layout Figure | Configuration Advantages | Configuration Disadvantages | Runway Capacity |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| Single Runway | Fig.1.3 | - lesser impact on environment due to reduced apron area and reduced aircraft movements per hour.<br>- Runway utilization often high.<br>- Choice of IATA. | - Airport capacity restricted by single runway traffic movements capability.<br>- Runway emergencies and maintenance more difficult to manage.<br>- Cross wind take off and landing can present problems. | 36-55 Mvts/Hr |

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Open "V" to "L" Runways | Fig.1.4 | - Increased runway Mvts/Hr yields increased airport ultimate capacity.<br>- Varied runway orientations can overcome seasonal prevailing cross wind problems.<br>- Runway emergencies and maintenance easier to manage (subject to case)<br>- Both runways can be used simultaneously | - Not a recommended choice of IATA.<br>- larger impact on environment than a single runway and some parallel runway configurations.<br>- occupies larger apron plan area.<br>- not naturally lend itself to efficient apron expansion.<br>- Aircraft crash at apex of "V" to "L" can render both runways in operative | 85-90 Mvts/Hr |
| Intersecting Runways | Fig. 1.5 | - Varied runway orientations can overcome seasonal prevailing cross wind problems.<br>- Runway emergencies and maintenance easier to manage (subject to case). | - Not a choice of IATA.<br>- Both runways cannot be used simultaneously.<br>- larger impact on environment than parallel runway.<br>- occupies larger apron plan area than single runway or parallel configurations.<br>- not naturally lend itself to efficient apron expansion.<br>- Aircraft crash at intersect point can render two runways | 70-75 Mvts/Hr |

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Staggered Runways | Fig. 1.6 | - Runway utilization can be high.<br>- Runway emergencies and maintenance easier to manage.<br>- Dedicated takeoff and landing runway operations promotes safer multiple runway operations<br>- Runway layout naturally lends itself to efficient apron expansion.<br>- Choice of IATA | - Cross wind take off and landing can present problems | 60 Mvts/Hr |
| Dual Parallel | Fig. 1.7 | - Runway utilization can be high.<br>- Runway emergencies and maintenance easier to manage.<br>- Dedicated takeoff and landing runway operations promotes after multiple runway operations.<br>- Runway layout naturally lends itself to efficient apron expansion.<br>- Choice of IATA | - Cross wind take off and landing can present problems | 84-105 Mvts/Hr |

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Multiple Parallel | Fig. 1.8 | - Runway utilization can be high.<br>- Runway emergencies and maintenance easier to manage<br>- Dedicated takeoff and landing runway operations promotes after multiple runway operations.<br>- Runway layout naturally lends itself to efficient apron expansion.<br>- Choice of IATA | - Cross wind take off and landing can present problems | 120-168 Mvts/Hr |

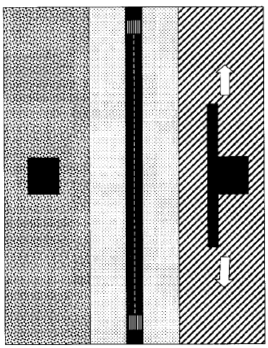


Fig. 1.3. Typical Single Runway Zone Diagram

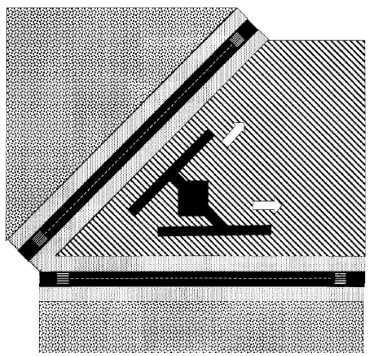


Fig. 1.4. Typical Open 'V' To "L" Shape Runway Zone Diagram

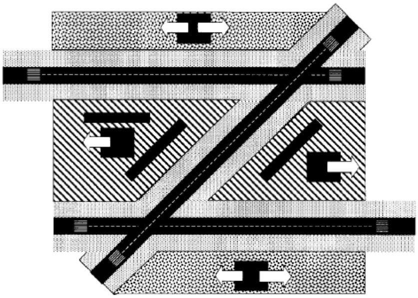


Fig. 1.5. Typical Intersecting Runway Zone Diagram

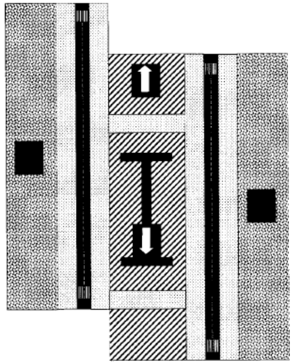


Fig. 1.6. Stragged Runway Zone Diagram

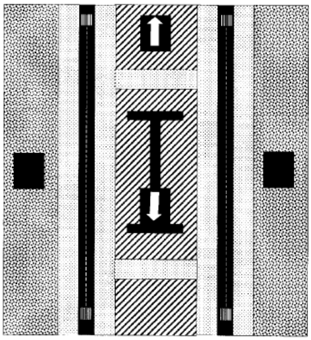


Fig. 1.7. Typical Parallel Runway Zone Diagram

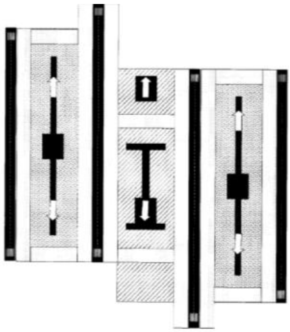


Fig. 1.8. Typical Multiple Parallel Runway Zone Diagram

Note: Conventions to fig. 1.3 – 1.8:

*Denote primary development zone*
*Denote taxiway system*
*Denote secondary development zone*
*Denote terminal or cargo infrastructure*
*Denote likely development expansion direction*

**3.** Runways are made up of seven elements, all of which perform a different function (Table 1.3) [9].

Table 1.3. Runway elements definition

| Apron Element | ICAO Annex 14 Definition |
|---|---|
| Runway | A defined rectangular area on a land aerodrome prepared for the landing and take off of aircraft. |
| Shoulder | An area adjacent to the end of the pavement so prepared so as to provide a transition between the pavement and the adjacent surface |
| Taxiway strip | An area including a taxiway intended to protect an aircraft operating on the taxiway and to reduce the risk of damage to an aircraft accidentally running off the taxiway. |
| Movement Area | The part of an aerodrome to be used for the take off, landing and taxiing of aircraft, consisting of the maneuvering area. |
| Manoeuvring Area | The part of an aerodrome to be used for the take off, landing and taxiing of aircraft, excluding the aprons. |
| Runway Holding Position | A designated position intended to protect a runway, an obstacle limitation surface, or an ILS/MLS critically sensitive area at which taxiing aircraft and vehicles shall stop and hold, unless otherwise authorized by the aerodrome control tower. |
| Stop-way | A defined rectangular area on the ground at the end of take run available prepared as suitable area in which an aircraft can be stopped in the case of an abandoned take off. |

## Lecture #1.5

## Aircraft Ground Handling

Plan

1. Basic requirements and approach to aircraft ground handling.
2. Deplaning and boarding.
3. Classification of passenger boarding bridges.

**1.** Airline companies are the most important customers of any airport. Airlines can minimize their extra investment for growth by increasing aircraft daily utilization. Many low cost carriers define the standards for time-effective handling quite strictly. Most of them require turnaround time not to exceed 25 minutes for a standard Boeing 737 en-route operation. A well-known phrase 'the airplane earns only when flying' holds true. Therefore, the basic requirements all airlines place on the ground handling (fig. 1.9) are:

- to ensure safety of the aircraft, avoiding damage to it
- to reduce ground time
- to ensure high reliability of handling activities, avoiding delays.

Three basic approaches to ground handling can be identified:

- the aircraft own technical equipment is used as much as possible
- mobile technical equipment of the airport is used as 'classical approach'
- airport fixed distribution networks with a minimum of mobile facilities, often called a 'vehicle free apron'.

***The choice of a particular approach to ground handling is basically influenced by the following:***

- airport size and its throughput;
- type of flight, short and long-distance;
- availability of capacity at the airport;
- the intensity of utilization of a particular stand;
- aircraft size;
- environmental concern of the population [10].

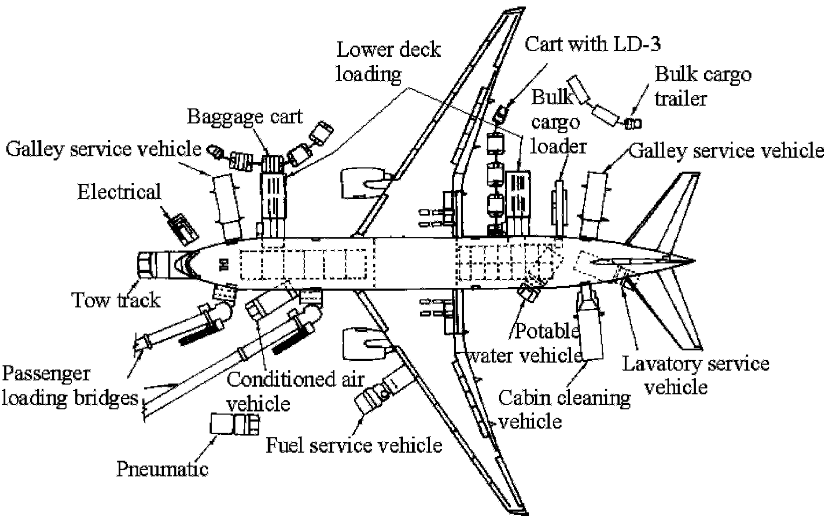



Fig. 1.9. The B-777 being serviced during a turnaround with the help of ground support systems and mobile equipment

**2.** ***Deplaning and boarding can be provided by means of:***

- stairs carried by the aircraft;
- mobile stairs;
- mobile lounges;
- passenger bridges.

A combination is also possible, e.g. a bridge attached to the aircraft door behind the crew cabin and mobile stairs for the rear exit. Although passenger bridges are more costly than mobile stairs, the former are increasingly used also at medium-sized airports. One of their advantages is that passengers can change between aircraft more quickly. While the aircraft is being boarded or deplaned, other servicing activities, including the aircraft refueling, can be carried out simultaneously. The movement of the servicing vehicles across the apron is not obstructed. The safety of passengers is also ensured as the contact of passengers with servicing vehicles is avoided.

The passenger boarding bridge can significantly reduce disembarkation and embarkation times when compared to conventional steps and vehicle lifts. Passengers typically move nearly 25% faster through passenger boarding bridges than compared to other alternative processes, since the process does not incorporate movement of buses with corresponding passenger dwell periods [10].

Passenger boarding bridges improve the passenger experience particularly in more extreme climates, since the passenger can be transferred to and from the aircraft in controlled climates and away from adverse weather such as rain, snow and extreme humidity and sunshine.

**3.** There are three types of passenger boarding bridge:

- The apron drive passenger boarding bridge.
- The nose loader passenger boarding bridge.
- The cantilever passenger boarding bridge.

*The apron drive passenger boarding bridge* (fig.1.10) provides the greatest flexibility for airports wishing to serve a wide range of aircraft, as it moves in 3 axis degrees of freedom, namely:

- Axis 1 — Vertically up and down about the pivot point on the rotunda.
- Axis 2 — Laterally in and out via the telescopic section movement.
- Axis 3 — On an arc rotating about the rotunda.

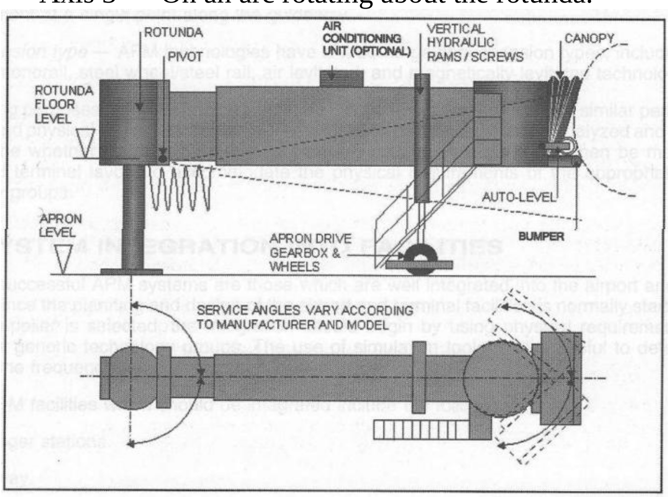



Fig. 1.10. Typical sections of apron drive passenger boarding bridge

*The nose loader passenger boarding bridge* is most commonly used to support aircraft which share similar or closer door sill heights, as the nose loader passenger boarding bridge can only move in two axis of freedom, namely:

- Axis 1 — Vertically up and down about the pivot point on the rotunda.
- Axis 2 — Laterally in and out via the telescopic section movement.

*The cantilever air bridge* is rarer than most passenger boarding bridges and used mainly to expedite passengers more quickly from large aircraft such as the Boeing 747 series or the Airbus A380 using the aircraft's aft port door positions. The cantilever passenger boarding bridge is usually used alongside a conventional apron drive unit serving the forward door positions. A nose loader combination is possible, though this is a very rare as it is also very restrictive.

The cantilever passenger boarding bridge extends over the port wing and engine(s) to reach the at port door on the aircraft. The cantilever structure is used since the weight of the telescopic sections cannot in this extension be supported by ground driven powered wheel assemblies. The load is instead transferred across the upper bracing structure which is predominately in tension, where the main weight and dynamic moments of the assembly are transferred to the upper sections of the rotunda [12, 13].

## Control questions to Module #1

1. History of airports development.
2. Perspectives of airports development.
3. Explain airport structure.
4. What are the core functions of an airport?
5. Notion about airport master plan.
6. Describe steps sequence of airport master plan developing.
7. What is airfield configuration?
8. Concept of runway capacity.
9. Numerate and define the runway elements.
10. What are basic requirements to aircraft ground handling?
11. What are basic approaches to aircraft ground handling?
12. Classification of passenger boarding bridges.
13. Notions about deplaning and boarding.

14. Define runway, taxiway, runway holding position.
15. What is the concept of ICAO Annex 14?
16. Determine configuration disadvantages of a single runway.
17.Determine configuration advantages of open “V” to “L” runway.
18. What are advantages and disadvantages of straggered runways?
19. What is the difference between dual and multiple parallel?
20. Advantages of the intersecting runway and its capacity.
21.Define aircraft type and mix, runway design, and aerodrome design.
22.What are engineered runway capacity and operational runway capacity?
23. Draw typical single runway zone diagram and typical open “V” to “L” shape runway zone diagram, then describe their concept.
24. Define shoulder, movement multiple area, manoeuvring area, and stop-way.
25. What does a nose loader boarding bridge mean?
26. Can you explain the concept of cantilever air bridge?
27. Notion about apron drive passenger boarding bridge?
28. What is the purpose of a master plan?

## MODULE #2. AIR PASSENGER AND CARGO TERMINALS

### Lecture #2.1

### Air Passenger Terminal Design Principles

Plan

1. Functional passenger terminal layout.
2. Requirements to passenger terminal design.

**1.** The *terminal* is often the first point of contact with the country for the arriving passenger. It is a shop window of the country and makes the first and, on departure, also the last impression on the passenger. From the architectural point of view terminals have always been and they still are a show piece representing the best of a particular country. It is, however, necessary to give priority to the functionality of the building by a suitable layout of the terminal (fig. 2.1) and the way it is operated if the passenger is to go away or enter with a good impression. The design of the building depends not only on the number of the checked in passengers but it must also have regard for the type of the airport operation, in particular whether the airport is predominantly an airline hub or is serving mostly local point to point traffic.

The main function of a terminal is to provide a convenient facility for the mode transfer from ground to air transport, and vice-versa [10].

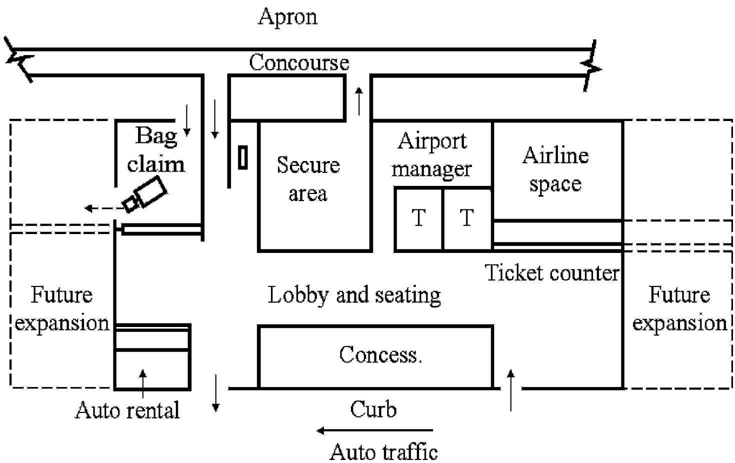



Fig. 2.1. Example of a functional passenger terminal layout

**2.** The design of an airport terminal is affected by the composition of the mix of passengers and by their requirements. For example, in airports with a great proportion of charter flights, the concourse in front of the check-in counters must be sufficiently deep and must offer enough space to cope with the inevitable long queues of passengers arriving in large batches and being processed through a small number of check-in desks. Airports with a high proportion of business travellers must offer them fast check-in and the shortest possible distance to the planes. It is therefore important, before starting the design of the terminal building, to know the type of airport operation, type of passengers, their composition and their requirements.

***The terminal building layout must in particular provide:***

- terminal – air-side connection;

- terminal connection to the land-side surface transport system;
- as short as possible walking distances of arriving and departing passengers;
- information for the passengers during the whole series of processes;
- convenient connection for transfer and transit of passengers;
- baggage-handling system for local and transfer bags;
- airside/landside security screen;
- government controls;
- appropriate sizing of all areas;
- required mix and quantity of aeronautical and non-aeronautical services.

The demarcation between the airside and the landside is usually within the terminal, marked by a security screen, the airside of which is subject to strict control of access prior to the boarding process. The landside is usually open access from where the passengers are dropped off their ground transport, through ticketing and check-in and up to the airside barrier.

At an airport with a great number of transit and transfer passengers the airside transit part of the terminal has to be dimensioned sufficiently and must be equipped with the systems for transportation of the passengers so that it allows them to circulate rapidly and thus ensure short declared times between the connecting flights. The departure and arrival concourses can in this case be smaller. At the airport with mainly origin/destination traffic an increased attention has to be paid to the design of the departure concourse of the terminal.

Terminal design criteria include: easy orientation for the travelling public approaching the terminal and within the buildings; shortest possible walking distances from car parks and rail station to the terminals and more importantly from passenger/baggage processing facilities to the aircraft and vice versa; minimum level changes for passengers within the terminal buildings; avoidance of passenger cross-flows; shortest possible distance for the transpofiation of passengers and their baggage between the terminals and the aircraft parking positions when walking is not possible.

Design should be modular to cope with future expansion of each subsystem or to allow evolution in regulations and changes in the nature of passenger flows and alliance groupings. Terminal design must meet all regulations for handling disabled persons [10, 12, 13].

## Lecture #2.2

### Air Passenger Terminal Concepts. Pier and Linear Concepts

Plan

1. Types of air passenger terminal concepts
2. Pier/finger concept, its advantages and disadvantages
3. Linear concept, its advantages and disadvantages

**1.** Each airport has its own individual design characteristics. However, ***all these designs can be narrowed down into 5 distinctive terminal concepts:*** opier/finger; linear; open apron; satellite; compact module unit terminal.

It should be noted that there are many variations in the respective shape of each of the noted major categories. In the past, airport authorities satisfied demand for new passenger processing facilities by unit terminal systems. These consisted of a combination of the above concepts (i.e. satellites, fingers, linear, etc.) in various shapes and sizes. Previous thinking was that each unit could function independently. This has proven not to be the case. Greater attention needs now to be paid to how airport should be planned efficiently and effectively in the longer term. Economies of scale, design, compact single operational systems, modularity and expandability are now the driving forces behind modern day terminal design [10].

**2.** *The pier/finger terminal concept* consists of a main centralized passenger processor and a series of piers (airside concourses). The main processor may consist of several semi-centralized check-in baggage reclaim areas fed by a common departures/arrivals curb. All Originating & Departing passengers and baggage are directed through the central processing area to and from the aircraft parking positions, which are connected to the central building by piers. Departing passengers are processed at centralized check-in facilities and walk to the respective gates, assisted by moving sidewalks installed in the piers. Baggage of all departing passengers is collected at the central check-in counters and conveyed to the-baggage sorting areas from where it is transported to the aircraft by mobile apron equipment or fixed conveying systems. Arriving passengers and their baggage are processed in the reverse flow.

Example of pier terminal concept: Amsterdam Schiphol, Bangkok, London Heathrow T3, Zurich. (fig.2.2) [10, 12, 13].

*Pier/Finger Terminal Possible Advantages:*

- a high percentage of passengers can be accommodated under one roof;
- it permits low Mean Connecting Time (MCT) if flight pairs are properly co-ordinated;
- it allows variable expansion possibilities of the piers, independent of the main processor;
- centralization of airline and government inspection services staff;
- it permits use of relatively simple flight information display systems.

*Pier/Finger Terminal Possible Disadvantages:*

- long walking distances, especially for transfer passengers;
- may require secondary concession outlets in piers;
- curbside congestion in peak periods;
- long taxiway routes to/from runways;
- requirements to segregate arriving/departing passengers may result in need to build a secondary passenger circulation level in some piers;
- early check-in and close-out times;
- high capital, operating and maintenance costs for passenger conveyance and baggage handling systems;
- potential for baggage mishandling.

**3.** *The Linear Terminal Concept* consists of a main centralized passenger processor with expansion capability to either side. On the front or airside face of the processor is a finger type concourse which may be straight or in another geometrical form. Aircraft are parked at the face and in some instances the rear of the concourse. An airside corridor may be located parallel to the terminal face with access to the terminal and gate positions. Departing passenger and baggage processing can take place either in a central area or at semi-centralized groups of check-in counters. Depending on the internal layout, the walking distance between the car park and reasonably short, in the case of a centralized processing system the distance may become unacceptably long. The size of baggage conveying and sorting systems depends on the internal layout of the building. This concept is mainly used if there is only confined space available between the landside road system and the runway [1, 10].

Examples of linear concept: Munich, Singapore Changi T2, Terminal 4 of London Heathrow (fig.2.3).

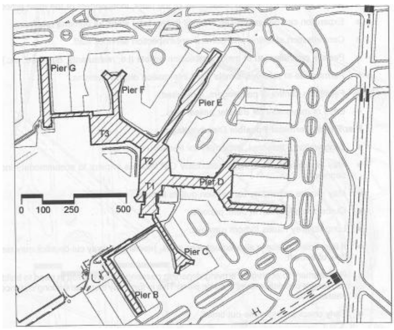



Fig. 2.2. Central terminal area of Amsterdam Schiphol (AMS), the Netherlands

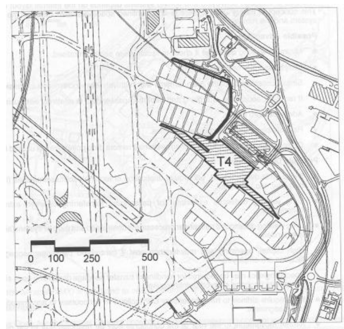



Fig. 2.3. Terminal 4 of London Heathrow (LHR), England

<u>*Possible Advantages:*</u>

- minimum walking distances if check-in facilities are semi-centralized;
- easy passenger orientation;
- simple construction of the main terminal with relatively easy incremental expansion;
- if required, separation of arriving and departing passengers is relatively easy using two levels;
- compact baggage conveying/sorting systems if remote drop points are not utilized in concourse.

*Possible Disadvantages:*

- if system is decentralized, it will require duplication of terminal facilities/amenities (i.e. restaurant, duty-free, etc.) and staff;
- long walking distances especially for passengers transferring between extreme concourses;
- aircraft movements to the rear of the concourse may be restricted due to the need to engine noise levels.

## Lecture #2.3

## Air Passenger Terminal Concepts. Open Apron, Satellite and Compact Module Unit Terminal Concepts

Plan

1. Open apron concept, its advantages and disadvantages.
2. Satellite concept, its advantages and disadvantages.
3. Compact module unit terminal concept, its advantages and disadvantages.

**1.** *The Open Apron Terminal Concept* consists of a main passenger processor with expansion capability on either side. Passenger transfers between the main processor and remote aircraft positions are accommodated by the use of apron drive busses or mobile lounges. There is no direct connection between the processor and aircraft parking positions. Departing passengers are processed at the central processing area and proceed through Government Inspection Services to a common departure lounge. ***From this point passengers can be handled in one of two ways:***

- they can be called to remote gate hold rooms, usually located at apron level, and then transported to the aircraft by bus;
- they can be called into mobile lounges which double as gate hold rooms and as transporters between the building and the aircraft parked at remote apron positions. The mobile lounges work with a scissor lift system that enables the lounge to operate at varying floor and aircraft sill levels.

*Possible Advantages:*

- constant compatibility of terminal/apron geometry to accommodate new generation large aircraft;
- ease of aircraft maneuverability (i.e. power-in, power-out operation);
- simplified passenger movement/orientation;
- reduced walking distances;
- a simpler, smaller and more efficient central processor.
- separation of arriving and departing passengers can be easily achieved;
- easy expansion capability for aircraft stands.

*Possible Disadvantages:*

- constant compatibility of terminal/apron geometry to accommodate new generation large aircraft;
- very low percentage of contact stands;
- increased loading/unloading processing times;
- additional airline staff required.

Examples of open apron (fig. 2.4): Montreal Mirabel (YMX), Washington Dulles & Paris Charles de Gaulle (CDG) [12, 13].

**2.** *The Satellite Terminal Concept* consists of a central processing building for passengers and baggage and remote concourses around which aircraft are parked. The remote concourses or satellites are connected to the main terminal by above- or below-ground links to facilitate the movement of passengers between the satellites and the main terminal. These links can be formed by either APM (Automated People Mover) systems or by underground walkways with travelators.

*Possible Advantages:*

- it normally provides for the centralization of airline and government inspection services staff;
- it permits short minimum connecting times within individual satellites;
- linear satellites permit direct aircraft routing between stands & runways;
- separation of arriving & departing passengers within satellites can be easily achieved if required;
- short walking distances (to/from APM).

*Possible Disadvantages:*

- high capital, operating and maintenance costs of baggage conveying/sorting systems with potential for baggage mishandling;
- individual traffic segments;
- due to distance and need to locate, wait and use APM system, minimum connecting times;
- early check-in and close-out times.

Examples of satellite concept: Denver (DEN), Atlanta, Paris CDG T1, Tokyo Narita T2 (fig. 2.5).

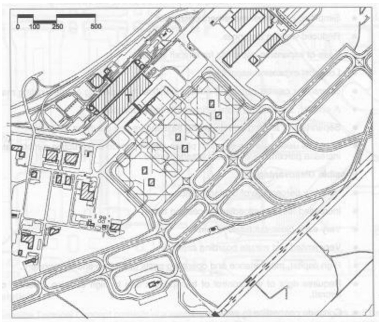


Fig. 2.4. Montreal Mirabel (YMX), Canada

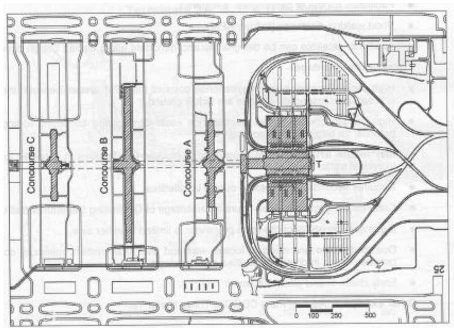



Fig. 2.5. Denver (DEN), USA

**3.** *The Compact Module Unit Terminal Concept* is a system witnessed in the past at small, medium and large airports. The hubbing need of base carriers and/or the major airline alliances has resulted in this type of solution becoming increasingly unpopular or obsolete with partnerships preferring collocation under one roof.

The transition of passenger and baggage from landside to airside and vice versa is directed through a compact facility which provides the shortest possible distance from the car park to the aircraft. Departing passengers and their baggage are processed either at a gate check-in or a semi-centralized flight check-in facility. Passenger moving equipment and outbound baggage sorting devices are usually not required within each module. The gate check-in procedure allows a very late check-in and close-out time. Arriving passengers and their baggage are processed in the vicinity of the gate in the reverse flow on the lower level.

*Possible Advantages:*

- short walking distances from check-in to aircraft;
- late check-in and close-out times (last minute baggage/passenger acceptance capability);
- greater curb lengths are provided than for centralized processing terminal units;
- within the terminal, only a simple flight information display system is required.

*Possible Disadvantages* (these occur when there is more than one terminal):

- low percentage of contact stands;
- difficulties in accommodating large volumes of passengers;
- individual terminal units are inflexible & incapable of major expansion;
- the complexity of land-side road access systems.
- higher manpower requirement - airline and government staff members will increase in order to operate multiple terminals.

Examples: Paris Charles de Gaulle (CDG), Terminals 2a, B, C & D; Budapest, Dallas Forth Worth & Hanover (fig. 2.6) [12, 13].

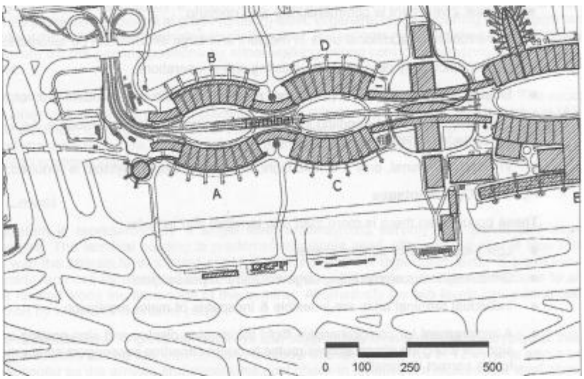



Fig. 2.6. Paris Charles de Gaulle (CDG), Terninals 2a, B, C & D – France

## Lecture #2.4

## The Airport Planning Process

Plan

1. Main planning items.
2. Features of planning items.

**1.** The airport should be planned such that passengers can easily orientate themselves within the buildings, without need of reference to signage systems. A transparent building philosophy should be adopted. The airport design should promote compatibility and flexibility to accommodate the changing needs of the airlines, should be compact to reduce travel distances, have minimal level changes and feel safe and secure to the passengers.

*The key planning items include:* Runway/Taxiway layout; Road/Rail access; Terminal design; Check-in hall; CUTE; Signage; Security; Airline Offices; Airline CIP Lounges; Terminal Retail Space; Departure Gate Lounges; Meeter/Greeter Hall; Apron Layout.

**2.** *Runway / Taxiway Layout.* Runway capacity is the most critical component at an airport. lt largely depends upon the number of runways and their layout and spacing. The key items that affect runway capacity are a combination of: availability of exit taxiways parlicularly Rapid Exit Taxiways (RETs) to minimise runway occupancy times; availability of a dual taxiway system; aircraft mix/pedormance;

*Access to the Passenger Terminal*.The public road system and the non-public or service road system should be planned carefully in order to avoid congestion near the passenger terminal. Traffic for the support facility areas of the airport should be handled on a separate road system so that truck traffic can be kept away from the main road to/from the passenger terminal. All public roads should be clearly sign posted. Signs should be properly lighted for night use and lettering and background colours should enhance clarity and visibility.

Carpark location should be closed to the passenger terminal. The connection between the car park and the terminal should have weather protection as well as arrival and departure curbside. Curbside check-in facilities may be required in some airporls.

*Terminal design.* The Passenger Terminal Complex should be designed in a modular fashion such that expansion of the terminal's inter-connected sub-systems can be easily and cost effectively achieved, without negatively impacting upon existing airline operations.

*Check-in Hall.* The passenger terminal layout is largely influenced by the check-in concept which is designed and installed by the airport authority. lt is essential therefore that airlines and handling agents be consulted at an early stage in the planning process. The airlines acceptance of passengers and their checked baggage takes place at the check-in facility, which consists of a number of check-in counters with appropriate outbound baggage conveyance facilities.

*CUTE (Common Use Terminal Equipment).* CUTE is an airline industry term for a facility, which allows individual users to access their host computers. The basic idea of the CUTE concept is to enable airlines at an airport to share passenger terminal handling facilities. This includes such areas as check-in and gate counters on a common use basis, enabling airlines to use their own host computer applications for departure control, ticketing, boarding pass and baggage tag issuance, etc., at such counters.

*Signage.* A well-conceived signposting system will contribute considerably to the efficient flow of passengers and traffic at the airport. lt is therefore essential to consider the signposting system in the ealrly planning and concept evaluation stages. The signage system may be a combination of fixed (boards, panels) and dynamic (monitors) signage. The signage system should be clearly separate from advertising.

*Security.* As stated in ICAO Annex 17, it is necessary to have clear government security standards which can be used by airport planners in such a way as to maintain the integrity of the local security programme, yet allow sufficient flexibility for them to be matched to the circumstances of each airport and its operations.

*Airline Offices.* Airline passenger processing support offices are required in close proximity to the check-in counters. The amount of space required by each airline and/or handling agency will vary depending upon such factors as volume of traffic or handling service performed.

*Airline CIP Lounges.* At many international as well as domestic airports, the airlines have a marketing providing special lounges to accommodate their Commercially Important Persons (CIP). This airline requirement has grown significantly in recent years to become a major customer service element in the way airlines handle their CIP passengers.

*Terminal Retail Space.* Recent surveys at airports show that passengers want, airports where they can browse when they have sufficient time. At some larger airports up to 10-20% of the terminal area is now dedicated to airports shops. With passengers willing to spend large amount of money on airport shopping, concession revenues can provide the airport with up to 50-60% of their total airport revenues.

*Departure Gate Lounges.* This lounge should be an open area, allowing passenger circulation. There should be seating in the area for 70% of passengers. It should be a quiet environment, with an apron view, where passengers can relax, work or enjoy themselves. lt should include facilities such as working positions with modem/internet and power connections, TV sets, smoking areas, children's play areas and retail and food concessions.

*Meeter-Greeter Hall.* Once passengers have claimed their bags and passed through customs formalities, they enter the Meeter/Greeter Hall where they can get organized before leaving the terminal. A well-designed entrance way or corridor out of customs into the Meeter/Greeter Hall is required to allow arriving passengers to avoid the congestion of greeters around the exit doors.

Important features of the meeter/greeter hall include: Meeting Point; Toilets; Currency Exchanges; Food and Beverage (F&B) facilities; Hotel and Tourist Information counters; Bus and Rail Information counters; Clear signage to taxis, buses, rail station and car parks.

*Apron Layout.* The key aspects of aircraft stand availability are: clear signage to taxis, buses, rail station and car parks; the number of stands provided for different types/sizes of aircraft; the availability of these stands as influenced by occupancy times.

Increasing importance is placed by airlines upon terminal gate stands because they provide for more rapid and comfortable handling of passengers, avoid the need for buses.

Service road ways should be clearly marked, with the width of each lane able to accommodate the widest piece of ground equipment. Areas such as equipment staging and parking must also be clearly marked [1, 10, 12, 13].

## Lecture #2.5

## Air Passenger Terminal Planning Standards

Plan

1. IATA planning standards and recommended practice.

**1.** The Airport Passenger Terminal should be designed to ensure functionality, maximum operational efficiency, passenger convenience at a reasonable cost, and be capable of further modular and incremental expansion. Such considerations as space for concessions and facilities for the general public should always be subordinate to the passenger space for processing and flow requirements, formulated by IATA (Table. 2.1). The main functional elements in the terminal building should be arranged in such a manner that the expansion of one element does not necessitate the relocation of other elements which may not require expansion [10].

Table 2.1. IATA planning standards

| Planning element | Planning Standard for Typical Busy Day | Recommended Practice |
|---|---|---|
| 1 | 2 | 3 |
| Airport Access | 90% of passengers can access the airport within 30 - 45 minutes of the CBD. | Express train service should be available every 15 - 20 minutes. |
| Check-in hall | Business Class- Maximum Queuing Time of 3-5 min. Economy Class – Maximum Queuing Time of 15-20 min. Tourist (Charter/ No Frills) class – Maximum Queuing Time of 25-30 min. Space - for passengers waiting up to 30 minutes 1.8m per international passenger, 1.3m for domestic passengers. | Island layout is preferred 16-18 counters per side. Separation distance between islands of 24-26m. |
| Security Screening | Maximum Queuing Time of 3-5min. Space for passengers waiting up to 10 minutes 1.0 $m^2$ per passenger. | |

| 1 | 2 | 3 |
|---|---|---|
| Outbound Passport Control | Maximum Queuing Time of 5min. Space for passengers waiting up to 10 minutes - 1.0 $m^2$ per passenger. | Introduction of biometrics will speed up processing. |
| CIP Lounges | 4.0 $m^2$ per passenger. | Preferred location for lounges is airside in normal passenger flow between check-in and aircraft gates. Arrival lounges may be required at large terminating airport. |
| Departures Lounge | Space - 1.2$m^2$ per passengers standing&1.7$m^2$ per passengers seated. Seating for 10% of passengers where passengers do not have to wait; 60% where passengers do have to wait. Space - 1.2$m^2$ per passenger standing&1.7$m^2$ per passenger seated. Seating – 70% of passengers should have access to seating, including seating at F&B (food & beverage) concessions. Walking Distance Maximums of 250-300m unaided&650m with moving walkways (of which not more than 200m unaided). APMs for travel over 500m. | WB aircraft should be parked close to the main PTB to reduce the walking distances for largest numbers of passengers. Gate lounge should include podium counter close entrance to PBB& include CUTE system with 2 boarding pass readers for aircraft larger than type C, a document printer& boarding pass printer. Shared baggage facility at the gate lounges for excess cabin baggages, trollers &wheelchairs. |
| Passenger Broarding Bridges | 90 – 95% of passengers (on an annual basis) will be serued by a passenger boarding bridge. PBB justified with minimum of 4-6 aircraft operations/day. | Apron drive bridges with 400 Hz fixed ground power, air conditioning & potable water attached. Ramps should be used to connect the PBB with the departures gate lounge (upper level) and with the arrivals corridor (lower level). |

| 1 | 2 | 3 |
| --- | --- | --- |
| Aircraft On-Time Performance | | Sufficient land for twin independent (1,800-2.000m separation) staggered parallel.<br>Runways (3500- 4000m length x 60m width) with space for 2 additional close parallel runways. |
| Inbound Passport Control | Maximum Queuing Time of 10 min.<br>Space - for passengers waiting up to 30 minutes 1.0m$^2$ per passenger. | Introduction of biometrics will speed up processing. |
| Baggage Glaim Hall | Wheel slop to Last Bag - Business Class: NB - 15 min, WB - 20 min; Economy Glass: NB - 25 min, WB - 40 min. Space - 13m$^2$ per passenger (excluding baggage claim unit). | Sufficient numbers should be provided to allocate at least one 85m baggage claim unit per 8747 flight.<br>Separate device(s) for handling oversize baggage. |
| Meeter - Greeter Hall | Space - 1.7m$^2$ per passenger and greeter. 20% of space for seating. | Easy access to train station. |
| Passenger Arrival - Wheel stop to Curbside | Business class - passenger on the curbside 20 - 25 minutes after aircraft arfival. Economy Class – passengers on the curbside 40-45 minutes after aircraft arrival. | |
| Wayfinding | | The PTB should incorporate self-evident passenger flow routes through the building, but where signs are required they must provide a continuous indication of direction. Signposting system should use a concise and comprehensive system of messages. Signposting should be in "mother tongue" and English. |

| 1 | 2 | 3 |
|---|---|---|
| Airline Oflices | $10m^2$ per staff member Rule of Thumb - # check-in counters $\times 100m^2$ | Sufficient space to lease to airlines & Alliances. Located landside reasonably close to check-in. Clearly signposted. |
| MCT - (Minimum Connecting Time) | Domestic-Domestic - 35-45 min.<br>Domestic-lnternational - 35-45min.<br>lnternational-Domestic 45-60 min.<br>lnternational-lnternational 45-60min. | |
| Passengers with Disabilities | Airport facilities must comply with national laws and regulations. | |
| Retail/ Concessions | | Airport Authority should obtain 50 – 60% of total airport revenue from retail/ concessions. 70-80% of retail concession should be located airside. Retail/ concession facilities should not interfere with passengers flows between check-in and the departure gate lounges. |

## Lecture #2.6

## Level of Service at Air Passenger Terminal

Plan

1. Types of level of service.
2. Capacity and level of service assessment.

**1.** *Level of service* can be considered as a range of values, or as assessments of the ability of supply to meet demand. To allow comparison among the various systems and subsystems of the airport and to reflect the dynamic nature of demand upon a facility, a range of level of service measures from A through to F may be used, similar to the standard employed in highway traffic engineering.

There exists the level of service framework as follows:

***A*** **-** An Excellent level of service. Conditions of free flow, no delays and excellent levels of comfort.

***B*** **-** High level of service. Conditions of stable flow, very few delays and high levels of comfort.

***C*** **-** Good level of service. Conditions of stable flow, acceptable delays and good levels of comfort.

***D*** **-** Adequate level of service. Conditions of unstable flow, acceptable delays for short periods of time and adequate levels of comfort.

***E*** **-** Inadequate level of service. Conditions of unstable flow, unacceptable delays and inadequate levels of comfort.

***F*** **-** Unacceptable level of service. Conditions of cross-flows, system breakdowns and unacceptable delays; an unacceptable level of comfort.

Since the traffic demand at each airport is dynamic and varies according to such factors as schedule flight sector, and aircraft size and load factor, the level of service measures must reflect these dynamic aspects. In this sense, the nature of the traffic demand plays an important role in affecting the level of service experienced by a passenger.

Managing terminal capacity and designing with level of service in mind are key requirements in the development of competitive airports, and have long-term financial and operational implications for passenger facilities. Level of Service C is recommended as the minimum design objective, as it denotes good service at a reasonable cost. Level of service A is seen as having no upper bound [10].

**2.** *Capacity* is a measure of throughput or system capability. Since a terminal system is capable of operating at varying degrees of congestion and delay, capacity must be related to the level of service being provided. Capacity and level of service calculation are a key step in the following airport development processes:

1. Airline strategy, traffic assignments and forecasts.
2. Planning peak period demand and planning schedules.
3. Facility requirements and level of service assessments.
4. Balance capacity and evaluate concepts.
5. Design, land use plan, master plan,
6. Programming.
7. Construction.

The occupancy patterns in various subsystems change rapidly and thereby affect the space available to occupants. In addition, the occupancy time for a subsystem can vary, resulting in a change, in comfort for this reason, time is a significant factor in determining the quality of service and must be considered as a primary variable in level of service measures.

ICAO has set a goal of 45 minutes for the clearance of arriving passengers, from disembarkation to exit from the airport, for all passengers requiring not more than normal inspection at international airports. Table 2.2 shows maximum queuing time guidelines [9].

Table 2.2. Level of service maximum waiting time guidelines

| Planning item | Short to acceptable, min | Acceptable to long, min |
|---|---|---|
| Check-in Economy | 0-12 | 12-30 |
| Check-in Business Class | 0-3 | 3-5 |
| Passport Control lnbound | 0-7 | 7-15 |
| Passport Control Outbound | 0-5 | 5-10 |
| Baggage Claim | 0-12 | 12-18 |
| Security | 0-3 | 3-7 |

## Lecture #2.7

## Major Functional Areas of Air Passenger Terminal

Plan

1. Purposes of check-in hall.
2. Features of the others functional areas.

**1. Departures concourse or check-in hall**

The departures concourse consists of various public and non-public areas. These include circulation and waiting areas, public facilities, airline ticket sales and service counters and check-in facilities (passenger and baggage).

*The circulation and waiting areas* extend from the front facade of the terminal up to the front of, or in some cases immediately behind, the check-in facilities. The total area includes a general circulation area parallel to the facade, a public seating area, a queuing area for passengers in front of the check-in counters, and an additional passenger circulation area either in front of or behind the check-in counters depending upon the actual check-in counter layout.

*Public Facilities* include the concessions, telephones, airport information desks, toilets, etc. Such facilities should be located in areas, which are not contiguous to the check-in facilities, in order to promote the most efficient and uniform utilization of the concourse areas.

*Airline Ticket Sales and Service Counters* are required for passengers, who have not purchased tickets prior to arrival at the airport, and for passengers who wish to change reservations, flight class or pay for excess baggage.

*Check-in Facilities f*or maximum flexibility, space should be allocated for two inter-linked take-away belts within each check-in island. Each belt should be capable of supporting up to 20 desks (maximum). Check-in facilities should also take into account the needs of passengers travelling on e-tickets.

**2.** There also exist such major functional areas of the airport as follows:

- Baggage Handling Systems;
- Passport Control - Outbound & Inbound;
- Security Positions;
- <u>Departure Lounges:</u>

❖ *General*

Common departure lounges, gate lounges and transit lounges may occur in terminals as three separate areas, in combination, or as one. The design layout depends greatly on the traffic characteristics, government controls and airline procedures, as ***they apply to the three main categories of passengers who use departure lounge facilities, namely:*** originating passengers arriving from the landside; transfer passengers arriving at the airside and transferring to another flight who should be processed on the airside; transit passengers arriving at the airside and continuing their trip on the same flight, who should always remain on the airside.

❖ *Common Departure Lounge*

At most international airports, a common departure lounge should be provided to accommodate originating passengers, who have checked-in early and have cleared government controls, but who still await their boarding gate details. Transit and transfer passengers with long connecting times also tend to dwell in this area.

❖ *Gate Lounges*

Gate lounges and their associated circulation space are the main components of both finger piers and satellites. The maximum size of aircraft handled, the maximum number of gates proposed and the maximum assumed peak hour flows of arriving, departing, transfer and transit passengers in the ultimate stage will determine the width required to support assumed flows.

❖ *Transit Lounges*

At most airports, transit passengers who disembark from their aircraft during servicing are accommodated in either the gate lounge or the common departure lounge. lf local requirements make it necessary to provide a separate lounge for transit passengers.

- Airline CIP Lounges;

At many international as well as domestic airports, the airlines have a marketing requirement to provide special lounges to accommodate their Commercially Important Passengers (CIPs). This requirement has grown significantly in recent years to become a major customer service element, and most airlines will require generously sized space for their exclusive use.

- Airside Circulation;

The airside corridor, if any, is the walkway by which passengers move between aircraft, between aircraft and the baggage reclaim area on arrival, or between the lounges and aircraft on departure. The corridor should be large enough to accommodate forecast volumes of departing and/or arriving passengers and should be unencumbered with distractions, such as displays or advertising that detract from pertinent information regarding departure or arrival areas.

- Airline Operations Area;

The Operations Area is frequently the designation given to the area occupied by airlines and ground handling personnel, who handle the aircraft, while it is on the ground. It is usually located near the apron and includes the area required for the flight crew and flight attendants as well as airline and ground handling personnel assigned to ground service operations.

- Baggage Re-claim Area;

To assist way-finding and passenger orientation, consideration should be given to glazed partitions between reclaim areas and the meeter/greeter area. Although baggage delivery to the reclaim area should be in advance of passenger delivery, it would be prudent to locate support facilities such as cash dispensing machines and toilets in this area, as well as baggage trolleys, free of charge.

- Arrivals Concourse.

This facility provides a short-term waiting area for the meeters and greeters awaiting passengers, together with a separate circulating area. Information and ground transportation concession facilities should be provided for those passengers requiring such services.

## Lecture #2.8

## Check-In

Plan

1. Check-in concepts.
2. Types of check-in layout.
3. Check-in equipment.

**1.** The layout of the check-in-hall in the passenger terminal is largely influenced by the check-in concept. The allocation of check-in counters to the various airlines and alliances should be considered early in the planning surface. There should be a logical flow for all passengers, and particularly alliance passengers, between check-in, CIP lounge and the departure gate lounge.

***There are three typical check-in concepts that can be selected:***

- Centralized Check-in;
- Split Check-in;
- Gate Check-in.

*Centralized Check-in:* passengers and baggage are processed at check-in counters located in common, central area - usually the departure level of the terminal. The counters may be divided into sections specifically designated for individual airlines or flights or, alternatively, passengers may be free to check-in at any counter position.

*Split Check-in:* the check-in function is split between two or more locations within the terminal complex. For example, passengers and baggage may be accepted at central check-in counters, or alternatively at other locations around the airport.

*Gate Check-in:* passengers proceed with their baggage directly to the gate and are processed at check-in counters immediately in front of the appropriate gate lounge. A good example of this type of check-in layout is Hanover, Germany.

**2.** The airlines acceptance of passengers and their checked baggage takes place in the check-in hall, which consist of a number of check-in counters with appropriate baggage conveyance facilities. Check-in counters may be placed in either a linear type layout or an island type layout. Within each of the two main types of counter layouts, several variants exist.

The distance a passenger must carry his/her baggage to the closest terminal check-in point should be kept to a minimum. Most check-in layouts now include a CUTE system. The layout of the check-in halls is changing quickly to accommodate and increasing number of self-service kiosks.

Appropriate systems for the conveyance of passengers' baggage from the check-in counters to the baggage make-up area must be provided. The type of system may include a number of transitions and can be relatively complex, as in the case with centralized check-in, or very simple in the case of gate check-in.

***There is Linear Type Check-in Layout and Island Type Check-in Layout.***

*Linear type check-in layouts* may be used both for centralized check-in and for gate check-in. The counters may be arranged in an uninterrupted, linear layout or be spaced so as to passengers to pass between the counters after check-in (pass-through layout). This type of check-in layouts is not favoured since the check-in hall becomes long and narrow when a large number of counters are required (fig.2.6).

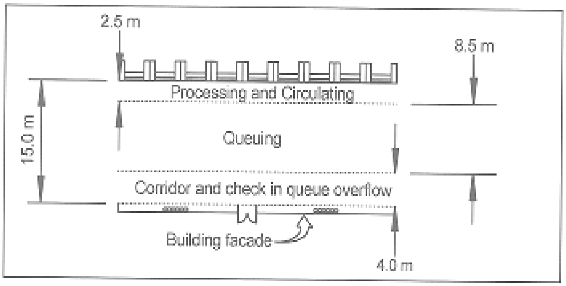



Fig. 2.6. Recommended dimensions for Linear Type Check-in Layout (maximum queuing time of 30-35 minutes)

*Island type check-in layouts* are suitable for centralized check-in. Each island, where the axis is orientated parallel to the flow of passengers through the terminal concourse, may consist of 10-20 individual check-in counters on each side. This number of counters on each side of the check-in island will require two main baggage conveyor belts installed in parallel back to back. Commonly 20-30m separation between adjacent islands is evident (fig. 2.7).

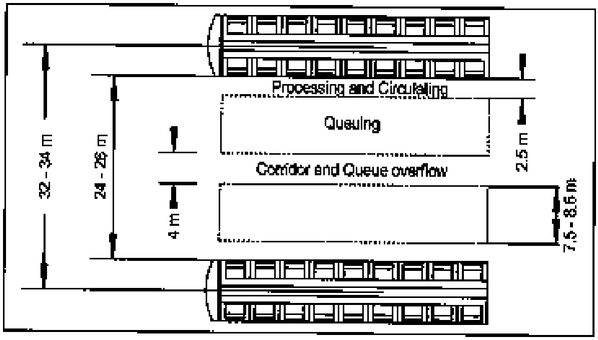



Fig. 2.7 Recommended dimensions for Island Type Check-in Layout with single queue per flight (maximum queuing time of 30-35 minutes)

**3.** The equipment which will be housed in the check-in counter includes computer monitor ( flat panel preferred); keyboard and CPU; boarding pass printer; baggage tag printer; document/itinerary printer; passport reader; telephone/interphone; conveyor controls; baggage scale readout. The PC and printer equipment is usually supplied by the CUTE supplier.

## Lecture #2.9

## Baggage Handling System

Plan

1. Core principles of baggage handling system design.
2. Baggage claim unit.

**1.** Baggage handling has become such a significant element of passenger processing that the baggage system is of major importance for a smooth airline operation at the airport. The baggage handling system must be able to sort large numbers of bags quickly and with a high degree of performance reliability. With larger capacity aircraft of future generation, the automated baggage system will become the most critical system in the airport terminal.

Certain terminal concepts may require highly automated and costly systems, while others may need only simple conveyor belts. Where automated distribution and sorting systems are contemplated it, is generally desirable to select the baggage handling systems supplier early in the project.

*The following core principles will contribute to an efficient baggage handling system:*

- baggage flow should be rapid, simple and involve a minimum number of handling operations;
- baggage flow should not conflict with the flow of passengers, cargo, crews or vehicles.
- baggage handling systems should incorporate the minimum number of turns and level changes as is practicable within the terminal design.
- baggage handling arrangements within the building should be consistent with apron arrangements and with the type and volume of traffic expected.
- provosion should be made for the forwarding of transfer baggage to the departure baggage sorting areas;
- flow on the apron should not be impeded by any form of physical controt or check;
- facilities for oversized baggage must be provided;
- check-in take away conveyors should be provided at each counter.

**2.** Claim units are located in the baggage claim hall, the area in the terminal where passengers reclaim their baggage off arriving flights. Currently, claim units of a recirculation type are widely used in airports. They allow the passengers to remain stationary, while their bags are delivered to them.

The space around a baggage claim unit serves distinct functions. Fig. 2.8 shows a typical layout. The baggage claim unit frontage provides the required positions or channels for the passenger to wait and collect their luggage. The retrieval area is effectively the space required for the motion of retrieving a suitcase. The peripheral area is used to wait for an opening in the retrieval area; for a passenger waiting for a friend to collect their luggage; to park the cart; and to circulate in/out of the retrieval area [10].

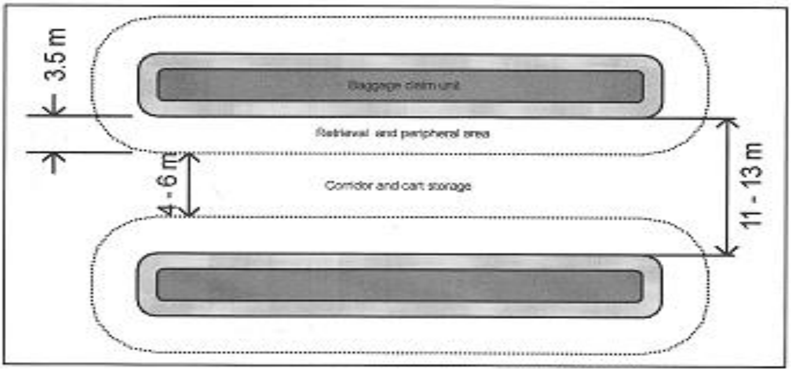


Fig. 2.8. Baggage Claim System

The retrieval and peripheral area is a roughly 3.5 meter wide band around the unit.

Departure conveyor systems have traditionally been one of the most, if not the most complex airport operational system. The departure baggage system can be a simple manual sortation system, or can be a fully automatic sortation system with integral intelligent hold baggage screening systems, transfer inputs and early baggage stores.

## Lecture #2.10

## Air Passenger Terminal Layout

Plan

1. Separation of passenger flows at the terminal.
2. Concept of air passenger terminal layout.

**1.** The terminal building is a connecting link between the air-side and the land-side. It is a connection between 'the sky and the earth'. The arriving and departing passengers must be physically separated, not only for fast and fluent movement of the passenger flows, but also in order to ensure security. The flows of passengers can be separated by fixed or moveable obstacles on a single level (horizontally) or on several levels (vertically).

The flow of passengers through the departing process must be direct, logical, limiting the changes on the vertical levels and as short as possible. Maximum walking distances for the passengers are recommended by the IATA as shown in Fig. 2.9 and described below:

- from the departure curb side in front of the terminal building to the check-in counter 20 m;
- from the farthest car park to the check-in counter 300 m;
- from the check-in counter to the farthest gate 330 m;
- from the gate to the plane 50 m.

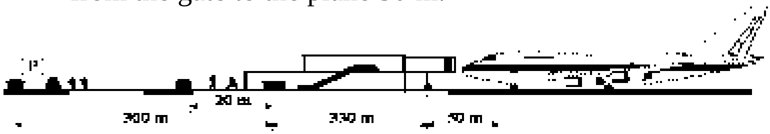


Fig. 2.9. Maximum IATA recommended walking distances

**2.** For small airports, a *single level concept* is the most suitable (Fig. 2.10a). In this concept the departing and arriving passengers and their baggage are separated horizontally, usually on the same level as the apron. The arriving passengers on domestic flights often do not even pass through the terminal building and the baggage is directly handed to them from the baggage cart under a shelter or even near the aircraft. Passenger loading bridges are not used in the single level concept [10].

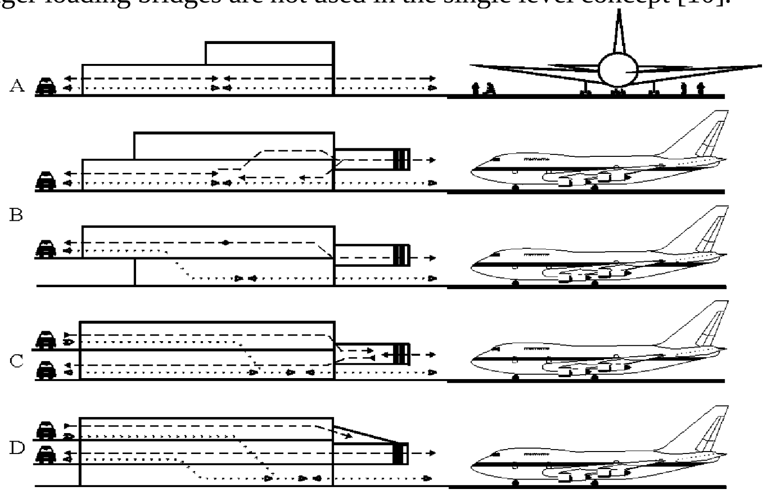



Fig. 2.10. Airport terminal layout; a) single level concept, b) one and half level concept, c) double level concept, d) three level concept.

If terminal buildings at larger airports were designed on a single level, the terminal would require large area of land. It then becomes more convenient to separate the passengers vertically. The simplest type of vertical separation is a concept of one and a half levels in several variants according to local conditions (Fig. 2.10b). Normally the departure and arrival landside concourses are on the same level side-by-side.

The division of flows of departing and arriving passengers and baggage can be done at any point after the check-in process or alternatively immediately after the entrance into the terminal building. Both levels meet again on the apron if the passengers are to walk or be bussed to the aircraft. However, if passenger loading bridges are regarded as necessary for passenger safety or as economically viable, the flows meet again at the entrance to the air bridge. In either case, departing passengers are held behind a barrier until all arriving passengers have been cleared into the terminal.

*The double level concept* provides separation of the passenger flows even on the landside by vertical stacking of the road access system, though with the capability to move between the levels inside the building (Fig. 2.10c). The double level concept is usually used for terminals with traffic volumes of above 5 million passengers a year.

In addition to the flows of arriving and departing passengers *the three level concept* also separates baggage vertically (Fig. 2.10, d). It is particularly advantageous to use this concept at airports where the baggage transport system and also other systems for technical handling have been designed below the level of the apron [10].

## Lecture #2.11

## Air Freight Terminal Design Principles

Plan

1. General information about air freight terminals.
2. Air freight terminal functions and operations.
3. Landside and airside design.

**1.** Freight, and particularly mail, has been moved by air for as long as passengers. The first official mail flight was from Frankfurt to Darmstadt by Lufthansa on 10$^{th}$ of June, 1912.

***Most of the products shipped by air fall into one of four categories:*** economically perishable goods; physically perishable goods; items for emergency maintenance; strategic inventory management.

Most of the freight is transported through a few large hubs. The top ten freight airports in the world in 2010 are given in Table 2.1.

**2.** There are five functions to be performed in the air freight terminal: conversion between modes of transport; sorting, including breaking down loads from originators and consolidating for destinations; storage, and facilitating government inspection; movement of goods from landside to airside and vice-versa, or from aircraft to aircraft; documentation: submission, completion, transmission.

Goods are usually moved from trucks into the terminal by trains of carts carrying bulk freight, pallets or containers pulled by tugs, preferably electrically powered. They are then manually off-loaded onto conveyers or taken by forklift to be sorted by destination. Either the sort process deposits the goods directly at the stuffing platforms or they are again taken by conveyor or forklift to the platform. The conveyor system for moving the goods inside the terminal can run to many kilometers in length. It is usually mounted high up to allow free movement of forklifts and ULDs at ground level. Packages up to a maximum of 30 kg are put into trays on the conveyers. The filled containers are then moved to the airside dock designated for the aircraft by a system of roller beds, or omni-directional ball-top beds if there are changes in direction involved. In the reverse direction, a similar process of movement occurs, except that the trucks back up to doors in the terminal so that they can be loaded directly under a canopy rather than having to be fed by tugs or forklifts [10].

Table 2.3. The top 10 freight airports

| # | Airport | Throughput [mil. t/year] | Growth 2009/2010 [%] | Leading carrier |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 1 | Memphis | 3.599 | 1.2 | Fedex |
| 2 | Hong Kong | 3.437 | 10.0 | Cathay |

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 3 | Anchorage | 2.609 | 9.7 | Fedex |
| 4 | Tokyo Narita | 2.290 | 3.5 | JAL |
| 5 | Incheon | 2.150 | 0.8 | Korean |
| 6 | Frankfurt | 1.963 | 6.7 | Lufthansa |
| 7 | Los Angeles | 1.929 | 1.4 | Fedex |
| 8 | Shanghai | 1.856 | 13.7 | China |
| 9 | Singapore | 1.855 | 3.3 | Singapore |
| 10 | Louisville | 1.815 | 4.3 | UPS |

**3.** *Landside design and operations.* The landside traffic delivering or collecting freight consignments includes private cars, flat bed trucks, vans of different sizes, lorries (some with their own handling systems) and special container vehicles. The vehicles need an efficient road access system, with 2 lanes and a total width of 10 metres, preferably dedicated to freight with its own access to the public road system. The access roads should, where possible, avoid centres of population, as both the size of the trucks and the frequent need to move at night can cause problems with local communities.

The trucks will often be backed up to individual doors in the terminal for collecting consignments, but may need to be parked adjacent to the terminal when delivering, with the consignments being taken to the terminal by forklift. The secure area behind the terminal needs to be deep enough to allow reversing to the doors and also for parking.

Arrangements must be made for the employees to get to work. With the emphasis on minimising the environmental footprint, efforts should be made to ensure there is public transport available. This is a particular problem when most of the freight activity is at night, as with the integrated carriers.

*Airside design and considerations.* The taxiway system should be free of capacity bottlenecks and minimise the in and out distances. The requirement is more important for integrator hubs, where many aircraft arrive almost simultaneously at night. This also requires runways to be aligned so that the arrival and departure routes avoid major centres of population and for taxiway routes to avoid directing engine exhausts towards the community. There should be unimpeded access to the freight apron.

The apron needs to have the capability to park all the all-freight aircraft likely to be on the ground at the same time, unless the maintenance or passenger aprons are close by and are likely to have spare capacity at the time of the freight operations.

The aircraft should be parked as near as possible to the freight terminal in order to reduce the amount ground traffic movement. This is essential if loading bridges are to be employed, though this normally only happens with nose-loading B747 operations. The freight transfer devices require a well-marshalled airside road between the terminal and the apron.

There should also be sufficient space for storing all the handling equipment and Unit Load Devices (ULDs). ULDs come in a large range of sizes and types, from 606×244×244 cm to 156×153×163 cm, some are rectangular, some are contoured to the shape of the fuselage, some are rigid, some are netted pallets, some have environmentally controlled interiors.

The ULDs are taken from the terminal on flat roller-bed dollies and loaded onto the aircraft main deck or belly holds using high-loader (Hi-Lo) vehicles fitted with driven roller beds (fig.2.11). Once inside the aircraft, they are transferred to roller beds on the floor of the aircraft, having been loaded in the correct order to achieve the necessary balance. Bulk freight is loaded manually into the belly holds, having been brought in carts to the apron by tug and transferred to the aircraft door by self-powered conveyors (fig. 2.12).


Fig. 2.11. Contoured ULDs on roller-bed dollies


Fig. 2.12. Bulk loading freight into a belly hold

There is a lot of movement of freight between the passenger and freight aprons at most airports. An airside road connection of sufficient capacity should be provided, with the capability support 10 tones per axle, 12 meters wide, a maximum of 4% gradient and a minimum turn radius of 20 m [10].

## Lecture #2.12

## Air Freight Terminal Layout and Sizing

Plan

1. Requirements to air freight terminal layout.
2. Air freight terminal mechanization.
3. Air freight terminal sizing.

**1.** The air freight terminal is a critical part in the air cargo supply chain. An inadequate air freight terminal concept that is unable to accommodate the peak volumes of freight may result in delays, while a concept that is not flexible enough to meet the changing demand may soon become obsolete during its service life.

A conventional freight terminal should be located as close to the passenger terminal as possible, commensurate with master planning indications to extend the facilities, and with geotechnical site constraints: earth-moving, drainage, utilities, etc. The freight terminal should also be as close to the runway as possible, without infringing on any of the runway transitional surfaces, either from the building or from the tails of parked aircraft.

The design of the terminal itself and the equipment with which it is fitted depends on: type of operator and their service standards; expected rate of growth of demand and the ultimate capacity required; political and economic setting; airport and local authority planning constraints.

Conventional freight terminals may be used by a single airline or forwarder, or by several different companies each with their own sections of the building. However, it causes duplication of the materials handling equipment, takes more space and increases the initial cost. Integrators usually construct and operate their own terminal. Target service standards also help to determine the staffing and facility requirements. Typical standards may be: consignments available for collection, examination or transshipment three hours after arrival; cleared consignments available within 15 minutes of consignee arriving at import collection point; customers to wait not more than 30 minutes after arrival for collection at truck dock; cargo reception to be complete within 30 minutes of arrival at truck dock.

The level of demand for conventional freight depends on the freight tariff, the time spent in transit, the frequency and timing of services, as well as the economic characteristics of the region. Most importantly, it is necessary to know whether the freight is to arrive and depart in bulk or on pallets or in small or large ULDs, and if the ULDs can be loaded direct from trucks that will be given access to the apron.

***The terminal design should take into account the need for a large number of facilities:*** potable water; electric power, and a standby system, clean for computers; lighting (200–300 lux at floor level, allowing effective colour reading and the use of PCs); fire detection and protection; heating and cooling; sewage disposal; garbage disposal; surface water drains; lightning protection; aircraft fuelling and ground power; communications (phones, computer cables, antenna sites); public address system; closed circuit CCTV; document and message conveyors [10].

**2.** All the above factors contribute to determining the level of mechanization to be provided for handling the freight. The choice is essentially between: *manual:* manpower plus fork lift trucks; *semi-mechanized:* roller beds or conveyors; *fully mechanized:* Elevating Transfer Vehicles (ETV); *automated:* automatic Storage and Retrieval Systems, Transfer vehicles.

The fully mechanized approach only really works with high volumes of containerized freight and in a setting that can guarantee good maintenance skills. Even so, the whole terminal can come to a halt if an ETV breaks down. ETVs work up to seven meters high with hydraulic or electric chain drive. Mechanization is much more expensive in terms of first cost, but reduces the labour requirement, causes less handling damage, less pilferage and there is less risk of mishandling. A semi-mechanized terminal may have belt conveyor systems and powered flat roller conveyors, where the rollers are chain-driven from the previous one.

**3.** Most terminals have only a single work floor, the inbound and outbound freight being processed side by side. Essentially, the flow moves towards the airside from the truck bays through de-stuffing, sorting, transfer, re-stuffing, weighing, screening and out to the airside dock, and vice-versa.

There are separate channels for international, domestic and transfer traffic. The minimum depth required from the aircraft nose to the landside boundary is: apron staging area - 18 m; airside road - 12 m; unit loading area - 6 m; terminal - 90 m; truck docks - 25 m; landside cargo road - 10 m. Resulting overall terminal depth is in total of 190 m, plus another 10m if aircraft are to be loaded through the nose. Columns should be kept to a minimum, subject to cost control. Some of the latest terminals have multi-level processing. A choice has to be made between handling ULDs either with the short side or the long side parallel with the terminal frontage. The former is good for storage. However, there are fewer build-up positions and a deeper building is required to get an adequate staging area.

IATA recommends that offices requiring direct access to the physical goods should be on the same ground level as the operations, while accounting and other offices should take advantage of the natural height of the building by being on a mezzanine. Canopies should be provided over the truck and airside docks.

In addition to providing the actual storage and flow of freight, the terminal building has to house facilities for a large number of ancillary support activities: supervising and control offices; airline offices; freight forwarder offices; customs inspection area and offices; agricultural inspection area and offices; security; operations offices; administration and support areas; customer service; battery charge area; maintenance and spare parts; plant room; staff support; aircraft spares and tools; refuse collection.

It will also be necessary to provide special accommodation for a number of special freights, all with their own requirements: vaccines, live organs, medicines – refrigeration; bullion, documentation - strong room, dedicated ‘airlock’ type vehicle docks or hopper systems; human remains - temperature control, mourning area; livestock - climate control, quarantine, partitioning for species, racking for small cages, veterinary support; dangerous goods; radio-active - shielding or spacing to meet exposure standards; airmail – secure; oversize or heavy freight; meat, fish, diary, flowers, plants – all need to be cooled.

Each type of special product needs its own separate work area for ULD build-up, sorting repackaging and quality control. Flowers and fruit need four to six degrees Celsius and 80 % humidity; fish need to be near zero degrees and near 100% humidity.

The size of the building is determined partly by the above factors, and also by the amount of freight delivered at one time, the expected dwell time, the density of the freight, the size of equipment, and the role of the terminal. The cubic capacity of a terminal depends on the design year throughput and the expected seasonal, weekly and daily peaking. The minimum height for processing is five meters, more for automated terminals with high storage racking [10].

The survey suggests that the average spatial productivity is 10 tonnes per year per m2 of total area for terminals handling more than 250,000 tonnes per year or 5 tonnes per year per m2 for small terminals with 50,000 tonnes per year. The data obtained by the survey are only approximate. IATA suggests that the main integrator hubs manage seven tonnes per year per $m^2$, while the smaller facilities can handle about five tonnes per year per $m^2$. Airside doors should be 5 meters wide and up to 5 meters high, while landside doors are normally 4 meters high by 3 meters wide. The width of terminal doors depends on the widths of the conveyor system's pallet dollies and the truck beds.

## Control questions to Module #2

1. Functional passenger terminal layout.
2. Requirements to passenger terminal design.
3. What are the types of air passenger terminal concepts?
4. Pier/finger concept, its advantages and disadvantages.
5. Linear concept, its advantages and disadvantages.
6. Open apron concept, its advantages and disadvantages.
7. Satellite concept, its advantages and disadvantages.
8. Compact module unit terminal concept, its advantages and disadvantages.
9. Determine the core planning items and their features.
10. IATA planning standards and recommended practice.
11. What types of level of service do you know?

12. What is capacity of service assessment?
13. Check-in concepts and their types.
14. What check-in equipment is used at the airport?
15. Notion about baggage claim unit.
16. Concept of air passenger terminal layout.
17. Separation of passenger flows at the terminal.
18. General information about air freight terminals.
19. What are the main air freight terminal functions and operations?
20. Landside and airside design of air freight terminal.
21. Make the list of the top 10 freight airports, their features.
22. What requirements should be applied to air freight terminal layout?
23. Air freight terminal mechanization.
24. Air freight terminal sizing.
25. Determine passenger terminal design, check-in hall, CUTE, airline CIP lounges, and meter-greeter hall.
26. What does inbound passport control mean? What do you know about outbound passport control? What is the abbreviation of minimum connecting time?
27. What do you know about public and check-in facilities?
28. Purposes of check-in hall.
29. Can you explain major functional areas of the airport?

## MODULE #3. AIRFIELD DESIGN

### Lecture #3.1

### Airfield Elements

Plan

1. Definitions.
2. Airfield classification.
3. Runway location and orientation.
4. Taxiway system.

**1.** *Airfield* is the portion of an airport that contains the facilities necessary for the operation of aircraft.

*Aircraft Operation* is the landing, takeoff or touch-and-go procedure by an aircraft on a runway at an airport.

*Runway* is a defined rectangular area at an airport prepared or suitable for the landing and takeoff of aircraft.

*Shoulder* is an area adjacent to the edge of paved runways, taxiways and aprons providing a transition between the pavement and adjacent surface; support for aircraft running off the pavement; enhanced drainage and blast protection.

*Threshold* is the beginning of that portion of the runway available for landing.

*Taxiway* is a defined path established for the taxiing of aircraft from one part of an airfield to another.

*Apron* is a specified portion of the airfield used for passenger, freight loading and unloading, aircraft parking, and the refueling, maintenance and servicing of aircraft.

*Based Aircraft* is the general aviation aircraft that uses a specific airport as a home base [1, 2, 4, 5].

**2.** ICAO (International Civil Aviation Organization) airfield classification consists of two code elements.

Code element number one depends on runway length (table 3.1) [5].

Table 3.1. Code Element 1

| Code | Runway length, m |
|---|---|
| 1 | < 800 |
| 2 | 800—1200 |
| 3 | 1200—1800 |
| 4 | > 1800 |

Code element number two depends on wingspan and gear width of aircraft (table 3.2).

Table 3.2. Code Element 2

| Code | Wingspan, m | Gear width, m |
|---|---|---|
| A | < 15 | < 4,5 |
| B | 15—24 | 4,5—6 |
| C | 24—36 | 6—9 |
| D | 36—52 | 9—14 |
| E | 52—60 | 9—14 |
| F | No limit | No limit |

**3.** Runway location and orientation are paramount to airport safety, efficiency, economics, and environmental impact.

Runway location and orientation depend on:

- wind velocity and direction;
- environmental factors (land use, impact of noise on nearby residents, air and water quality, wildlife, historical features);
- obstructions to air navigation;
- topography;
- airport traffic control (ATC) tower visibility (facility in the terminal air traffic control system located at an airport which consists of a tower cab structure and an associated instrument flight rules room, if radar equipped, that uses ground-to-air and air-to-ground communications and radar, visual signaling, and other devices to provide for the safe and expeditious movement of terminal area air traffic in the airspace and airports within its jurisdiction);
- wildlife hazards (in orienting runways, consider the locations of bird sanctuaries, sanitary landfills, or other areas which may attract large numbers of birds or wildlife; where bird hazards exist, develop and implement bird control procedures to minimize such hazards) [5].

**4.** As runway traffic increases, the capacity of the taxiway system may become the limiting operational factor. Taxiways link the independent airfield elements and require careful planning for optimum airport utility. The taxiway system should provide for free movement to and from the runways, terminal and parking areas.

Taxiways and intersections comprise the taxiway system. It includes entrance and exit taxiways (fig. 3.1), bypass taxiways (fig. 3.2), crossover taxiways, apron taxiways, parallel and dual parallel taxiways (fig. 3.3), right-angled exit taxiway (fig. 3.4), acute-angled exit taxiway.

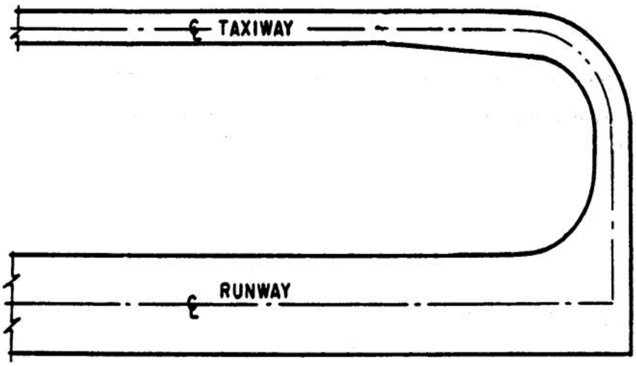



Fig. 3.1. Entrance taxiway

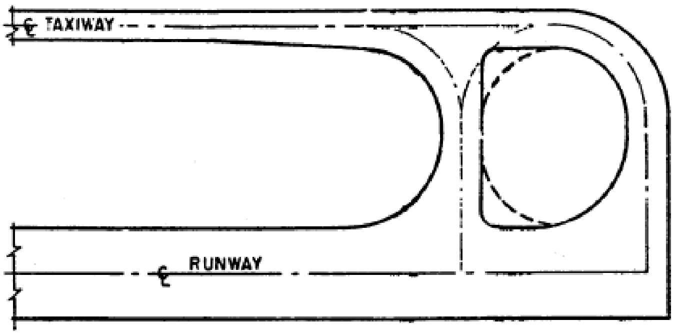



Fig. 3.2. Bypass taxiway

Design principles of the taxiway system [5]:
- provide each runway with a parallel taxiway;
- build taxiways as direct as possible;
- provide multiple access to runway ends;
- minimize crossing runways;
- provide airport traffic control tower line of sight;
- avoid traffic bottlenecks.

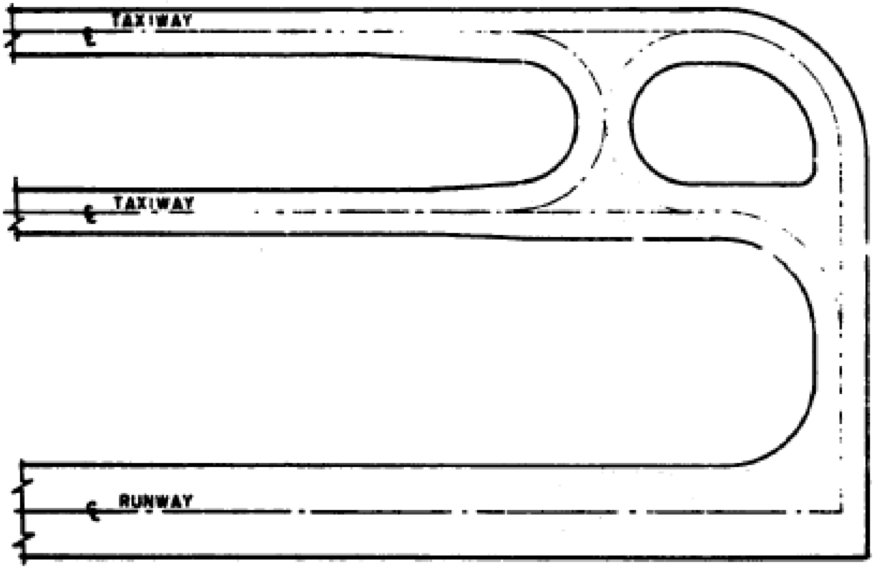



Fig. 3.3. Dual parallel taxiways

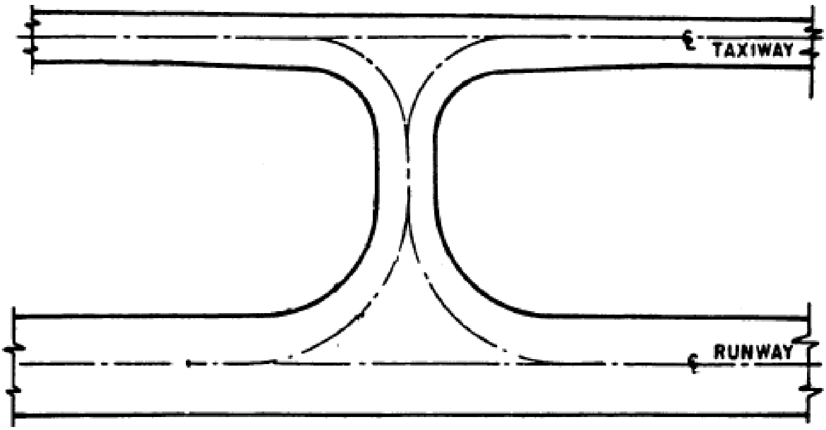



Fig. 3.4. Right-angled exit taxiway

## Lecture #3.2

## Airport Aprons

Plan

1. Definitions.
2. Apron area design.

**1.** *Apron* is a specified portion of the airfield used for passenger, freight loading and unloading, aircraft parking, and the refueling, maintenance and servicing of aircraft.

*Taxilane* is the portion of the aircraft parking used for access between taxiways and aircraft parking positions.

**2.** Four primary considerations govern efficient apron area design:

- the movement and physical characteristics of the aircraft to be served;
- the maneuvering, staging, and location of ground service equipment and underground utilities;
- the dimensional relationships of parked aircraft to the terminal building;
- the safety, security, and operational practices related to apron control.

The primary objective of these considerations is the ready accommodation of aircraft. This involves maximizing the total area in terms of aircraft parking with comparable relationships between these aircraft and the building. The optimum apron design for a specific airport will depend upon available space, aircraft mix, and terminal configuration.

There are 6 types of aircraft parking (fig. 3.5-3.10) [1, 2, 4].

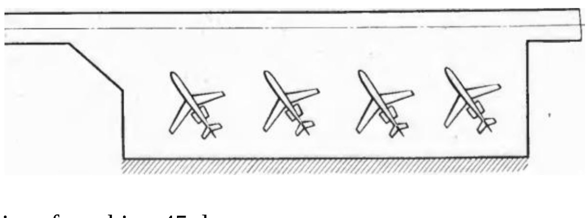


Fig. 3.5. Aircraft parking 45 degrees entry power out

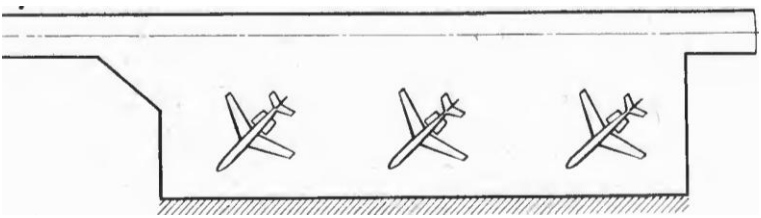


Fig. 3.6. Aircraft parking 45 degrees entry push out

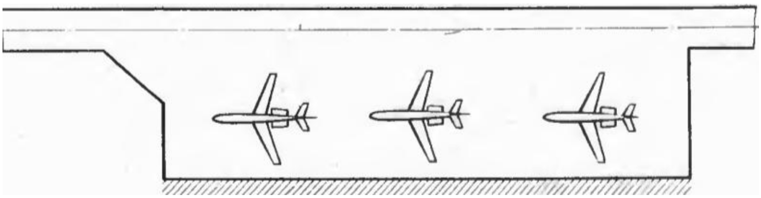


Fig. 3.7. Aircraft parking parallel in power out

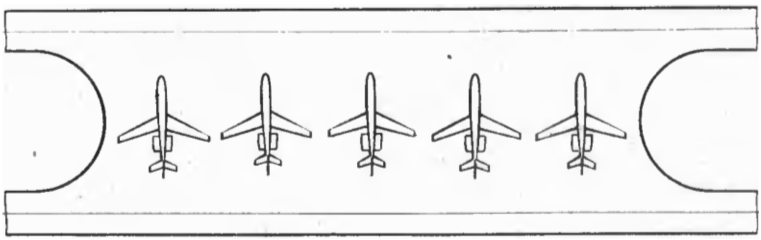


Fig. 3.8. Aircraft parking between two taxiways

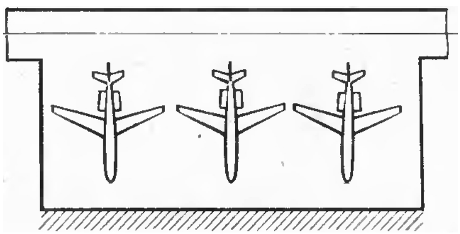


Fig. 3.9. Aircraft parking straight entry push back

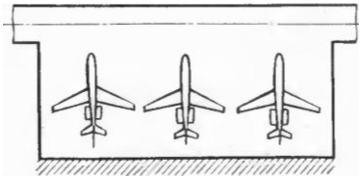


Fig. 3.10. Aircraft parking straight entry power out

Taxilanes are used on aprons by aircraft taxiing between taxiways and gate positions. The required taxilane object free area widths and provision of dedicated rights-of-way for apron service vehicle roads affect the minimum spacing between parked aircraft and between pier fingers.

Both single and dual taxilanes are used between pier fingers, depending on the pier lengths and number of aircraft positions. When a dual taxilane is under consideration, the frequency of use by each aircraft type, as well as the number of aircraft parking positions on each side, should be considered.

As a rule, a row of four aircraft on each side will not require a dual taxilane. For larger arrangements, a detailed analysis of aircraft movements and traffic delays may be necessary. Figures 3.11, 3.12 illustrate apron taxilane layouts with provision of dedicated space for service vehicle roads [1, 2, 4]. Figure 3.13 provides dimensioning information on pier separation with single and dual taxilanes.


Fig. 3.11. Apron single taxilane layout with service vehicle roads

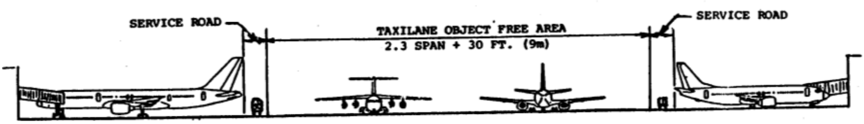



Fig. 3.12. Apron dual taxilane layout with service vehicle roads

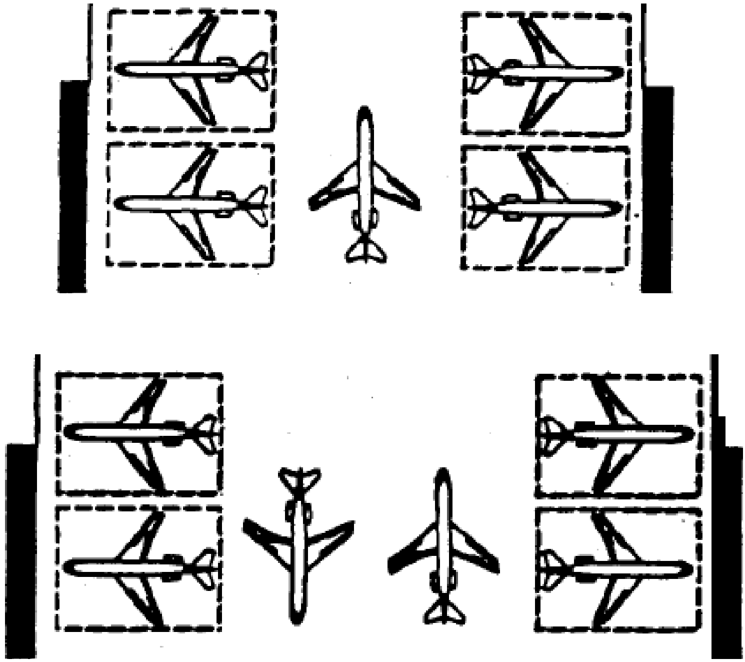


Fig. 3.13. Single and dual taxilane layout

For fueling, east of towing, and taxiing, apron gradients should be kept to the minimum, consistent with local drainage requirements. The slope should not exceed 1.0 percent and should be directed away from the face of the terminal.

## Holding Bays

Holding bays provide a standing space for airplanes awaiting final air traffic control (ATC) clearance and to permit those airplanes already cleared to move to their runway takeoff position. They enhance maneuverability for holding airplanes while also permitting bypass operations. A holding bay should be provided when runway operations reach a level of 30 per hour.

Although the most advantageous position for a holding bay is adjacent to the taxiway serving the runway end, it may be satisfactory in other locations. Place holding bays to keep airplanes out of the runway safety area.

Some typical holding bay configurations are shown in fig. 3.13. Paving area between dual parallel taxiways may provide an acceptable holding bay [1, 2, 4].

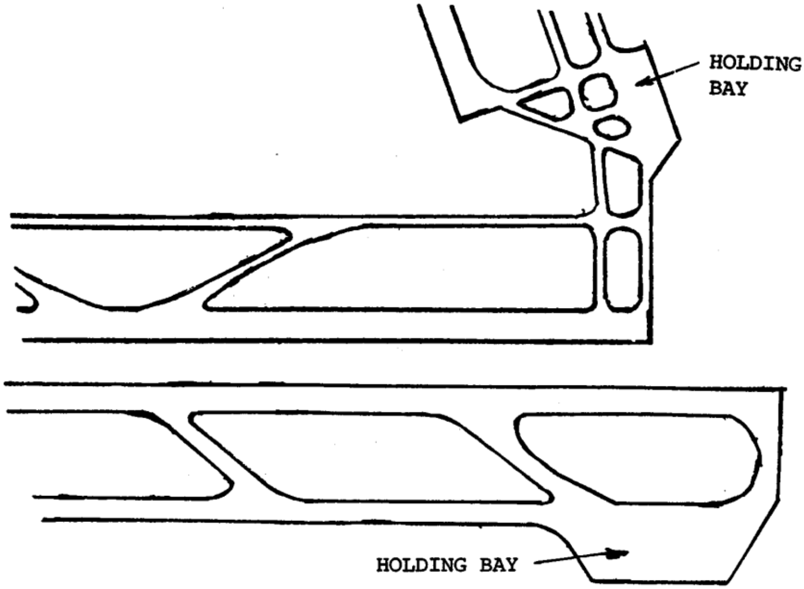



Fig. 3.13. Typical holding bay configurations

## Lecture #3.3

## The Drainage System

Plan

1. Characteristics and purpose of airport drainage.
2. Basic information required.
3. Drainage layout.
4. Drainage system design.

**1.** An airport should have smooth, well-drained operational areas with sufficient stability to permit the safe movement of aircraft under all weather conditions.

The drainage system should be built before or during the grading operations because draining and grading are interrelated. A drainage system cannot be expected to function properly unless the airport area has been correctly graded to divert the surface runoff into the system.

The large area that must be drained on average airport requires an economically designed drainage system. Sound engineering principles must be applied in the utilization of all available data, such as: topographic maps; soil reports; determinations of water tables; intensity, frequency and duration of precipitation; climate and temperature reports and nature of the surrounding the particular site.

The topography of the site and off-site areas affect the final layout of the runways, taxiways, aprons and buildings. The location and size of these facilities will control the grading and the extent of drainage required. It is important that the grading of the airport be such that all shoulders and slopes drain away from runways, taxiways and all paved areas. After final elevations on the airport has been determined, all surface flow of water onto the site must be intercepted and disposed of any low spots on the site must be drained, and all surface runoff must be accumulated and directed into adequate outfalls.

Enough tests should be taken to identify all soil types because texture, permeability and capillarity have a pronounced effect upon their drainability. Because of its effect on the stability of soils and on the ultimate design of the airport, the water table should be accurately determined over the entire area. When a high water table does exist, provision should be made for controlling or lowering it.

In designing a drainage system, it is important to determine expected precipitation at the airport site. Records of average accumulated snowfall would be pertinent to the drainage design.

The purpose of airport drainage is to dispose of water which may hinder any activity necessary to the safe and efficient operation of the airport. The drainage system should collect and remove surface water runoff from each area, remove excess underground water, lower the water table, and protect all slopes from erosion. Natural drainage does not meet these requirements. Constructed drainage facilities must be sufficient to provide for present requirements and any future enlargements of the system. This may mean the installation of a portion of a drainage system to supplement the natural drainage on the site or it may call for a complete system to drain the entire airport area. A proper understanding of all contributing drainage factors determines the extent of the facilities required on each particular airport [1, 2, 4, 6].

An inadequate drainage system can cause serious hazards to air traffic at airports. The most dangerous consequences of inadequate drainage systems are saturation of the subgrade and subbase, damage to slopes by erosion, loss of load-bearing capacity of the paved surfaces, and excessive ponding of water.

Aprons and other pavement should be sloped away from buildings.

**2.** Before any design can be undertaken, certain basic information and data must be available to develop and detail the drainage system. These data should consist primarily of the following items:

- the contour map of the airport and adjacent areas;
- the "drainage working drawing" showing the layout of the runways, taxiways, aprons and buildings areas;
- all rainfall data, such as frequency, intensity and duration of storms;
- plotted centerline profiles of all the runways, taxiways and apron areas with necessary cross sections;
- boring plans and soil profiles prepared on the basis of soil tests, including data on ground water elevation;
- temperature data, especially records on maximum and minimum temperatures during seasons of freezing and thawing and on depths of frost penetration; also, snowfall records indicating maximum and average depths of fall per month;
- data, when obtainable, on the infiltration properties of soils encountered and any actual runoff records for drainage areas in the locality having similar characteristics and soils;
- information on existing and future aircraft use for selection of appropriate strength for grates, covers and frames for inlets and manholes [1, 2, 4, 6].

**3.** With the general configuration of the terrain well in mind, actual layout of the drainage system can now be undertaken. This can best be done on the drainage working drawing, upon which have been placed the runway layout and the tentative finished grading. The finished contours reveal that a crown section has been used which is the standard cross section for the runways, taxiways and safety areas. This crowned section slopes each way from the centerline of the runway on a transverse grade to the edge of the pavement, except where it becomes necessary to warp the grade to provide a smooth transition at the intersection of pavements. The intermediate areas of the runway safety area, each side of the runway pavement will be on a transverse grade away from the pavement. This grade may be varied slightly to properly design for drainage inlets.

Several trial drainage layouts will be necessary before the most economical system can be selected. The first consideration will be the tentative layout serving all of the depressed areas in which overland flow will accumulate. The inlet structures will be located, during the initial step, at the lowest points within the field areas. Each of the inlet structures will be connected to the field pipelines, which in turn will be connected to the major outfalls.

After the field storm drain system has been tentatively laid out and before the actual computations have been started, the areas contiguous to the graded portion of the airport which may contribute surface flow upon it should again be studied. A system of open channels, intercepting ditches or storm drains should be designed where necessary to intercept this storm flow and conduct it away from the airport to convenient outfalls.

Ditches form an integral part of the drainage system. The size of the ditches and their functions are quite variable. Some ditches serve to carry the outfall away from the pipe system and drainable areas into the natural drainage channels or into existing watercourses. Sometimes it becomes necessary to construct extensive peripheral ditches. Their purpose is to receive outfall flow from the drainage system, to collect surface flow from the airport site or adjacent areas and to intercept possible ground water flow from higher adjacent terrain. Open ditches are liable to erode if their gradients are steep and if the volume of flow is large.

**4.** A step-by-step drainage procedure is as follows:

1) Identify the structures and establish the lengths of pipe elements between structures.

2) Select values for coefficients of runoff for the several types of surfaces over which water will flow.

3) Compute a weighted value of runoff coefficient if required.

4) Determine the distance from the inlet to the most “time-remote” point in the tributary subarea. If in flowing from such point, water traverses different types of surfaces, the lengths of flow over each type of surface should be determined.

5) Using the distances determined according to step (4), the time of flow to the inlet from the most “time-remote” point can be established. The time so determined is the “inlet time”.

6) Determine the time of concentration for the inlet.

7) From the plotted rainfall curve for the design storm, find the rainfall intensity for the corresponding time of concentration.

8) Record the acreage of the subarea which is contributing to the inlet.

9) Compute the quantity of runoff. This is the amount of water which must be accommodated by the drain pipe from this inlet.

10) Select slope and determine the pipe size which will carry the runoff [1, 2, 4].

## Control questions to Module #3

1. What does runway location depend on?
2. What are the main elements of the taxiway system?
3. What design principles of the taxiway system do you know?
4. What is the portion of the aircraft parking used for access between taxiways and aircraft parking positions?
5. How many types of aircraft parking do you know?
6. What code elements does ICAO airfield classification consist of?
7. What taxiway intersections do you know?
8. What characteristics of airport drainage do you know?
9. What is the purpose of airport drainage?
10. What are the characteristics of surface drainage?
11. What are the characteristics of subsurface drainage?
12. What steps does drainage design procedure include?
13. Airfield classification.
14. Drainage layout.
15. Basic information required for drainage design.

# MODULE #4. AIRPORT PAVEMENT DESIGN

## Lecture #4.1

## Airport Pavements

Plan

1. Function and purposes of airport pavements.
2. Pavement courses.
3. Pavement types.

**1.** Airport pavements are constructed to provide adequate support for the loads imposed by aircraft using an airport and to produce a firm, stable, smooth, all-year, all-weather surface free from dust or other particles that may be blown by jet blast. In order to satisfactorily fulfill these requirements, the pavement must be of such quality and thickness that it will not fail under the load imposed. In addition, it must possess sufficient stability to withstand, without damage, the abrasive action of traffic, adverse weather conditions, and other influences. To produce such pavements require a coordination of many factors as design, construction, and inspection to assure the best possible combination of available materials and a high standard of workmanship.

Pavements are divided into flexible, rigid, hot mix asphalt overlays and rigid overlays. Various combinations of pavement types and stabilized layers can result in complex pavements which would be classified in between flexible and rigid.

When properly designed and constructed, any pavement type (rigid, flexible, composite, etc.) can provide a satisfactory pavement for any civil aircraft. However, some designs may be more economical than others and still provide satisfactory performance.

Life-cycle cost analysis should be used if the design selection is based on least cost.

**2.** Pavement Courses:

*1) Surface.* Surface courses include portland cement concrete, hot mix asphalt, sand-bituminous mixture.

*2) Subbase.* Subbase courses consist of a variety of different materials which generally fall into two main classes, treated and untreated. The untreated bases consist of crushed or uncrushed aggregates. The treated bases normally consist of a crushed or uncrushed aggregate that has been mixed with a stabilizer such as cement, bitumen, etc.

*3) Subbase.* Subbase courses consist of a granular material, a stabilized granular material, or a stabilized soil.

*4) Geotextile.* Geotextiles are permeable, flexible, textile materials sometimes used to provide separation between pavement aggregate and the underlying subgrade. Geotextile needs and requirements within a pavement section are dependent upon subgrade soil and groundwater conditions and on the type of overlying pavement aggregate.

**3.** A flexible pavement structure is typically composed of several layers of material with better quality materials on top where the intensity of stress from traffic loads is high and lower quality materials at the bottom where the stress intensity is low. Flexible pavements can be analyzed as a multilayer system under loading.

A typical flexible pavement structure consists of the surface course and underlying base and subbase courses. Each of these layers contributes to structural support and drainage. When hot mix asphalt (HMA) is used as the surface course, it is the stiffest and may contribute the most to pavement strength. The underlying layers are less stiff but are still important to pavement strength as well as drainage and frost protection. A typical structural design results in a series of layers that gradually decrease in material quality with depth. A typical section for a flexible pavement is shown in fig. 4.1 [1, 2, 4, 6, 11].

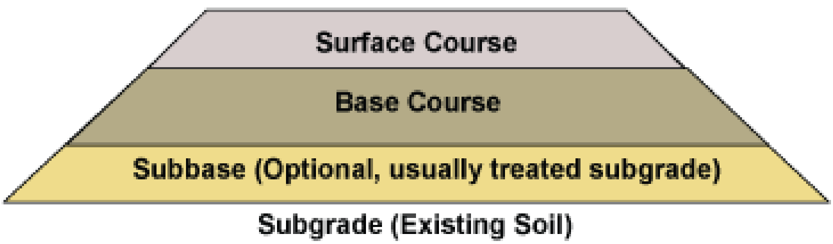



Fig. 4.1. Typical section for a flexible pavement

A rigid pavement structure is composed of a Portland cement concrete surface course, and underlying base and subbase courses (if used). The surface course (concrete slab) is the stiffest and provides the majority of strength. The base or subbase layers are orders of magnitude less stiff than the PCC surface but still make important contributions to pavement drainage, frost protection and provide a working platform for construction equipment. Rigid pavements are substantially stiffer than flexible pavements due to the high modulus of elasticity of the PCC material resulting in very low deflections under loading. The rigid pavements can be analyzed by the plate theory. Rigid pavements can have reinforcing steel. A typical section for a rigid pavement is shown in fig. 4.2 [1, 2, 4, 6, 11].

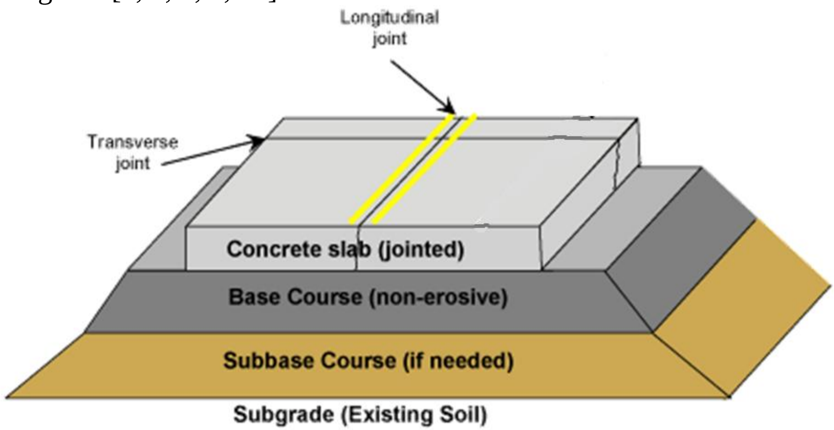



Fig. 4.2. Typical section for a rigid pavement

The primary structural difference between a rigid and flexible pavement is the manner in which each type of pavement distributes traffic loads over the subgrade. A rigid pavement has a very high stiffness and distributes loads over a relatively wide area of subgrade a major portion of the structural capacity is contributed by the slab itself.

The load carrying capacity of a true flexible pavement is derived from the load-distributing characteristics of a layered system. Figure 4.3 and 4.4 show load distribution for a typical rigid pavement and a typical flexible pavement.

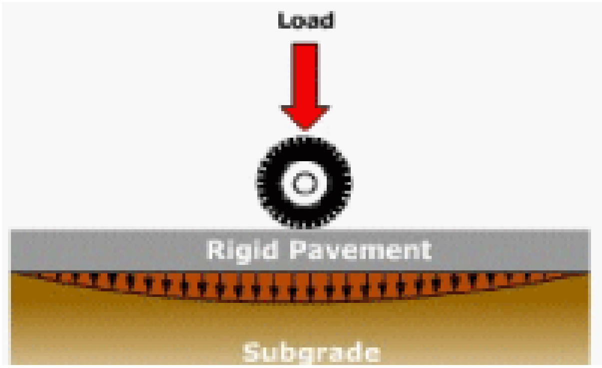



Fig. 4.3. Typical stress distribution under a rigid pavement

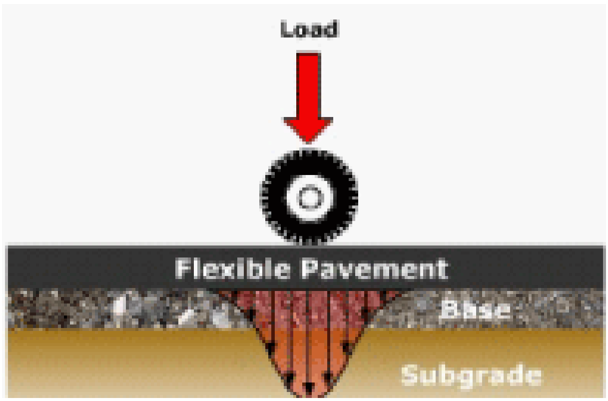



Fig. 4.4. Typical stress distribution under a flexible pavement

## Lecture #4.2

## Flexible Pavement Design

Plan

1. Types of flexible pavements.
2. Information needed for pavement design.

**1.** A true flexible pavement yields “elastically” to traffic loading and is constructed with a bituminous-treated surface or a relatively thin surface of hot-mix asphalt (HMA) over one or more unbound base courses resting on a subgrade. Its strength is derived from the load-distributing characteristics of a layered system designed to ultimately protect each underlying layer including the subgrade from compressive shear failure. Progressively better materials are used in the upper structure to resist higher near-surface stress conditions caused by traffic wheel loads and include an all-weather surface that is resistant to erosion by the environment and traffic action. The bituminous surface layer must also be resistant to fatigue damage and stable under traffic loads.

The elements contributing to the higher modulus may be:

1. increased thickness in asphalt concrete;
2. chemical stabilization of the base, subbase, and/or subgrade layers;
3. asphalt stabilization of the base course [1, 2, 4, 6].

The higher modulus adds to the structural capacity of the pavement layers. The load is distributed over a wider area of the subgrade.

Hot mix asphalt-surfaced pavements may generally be placed into one of the following categories:

- surface-treatment on a granular base
- thin hot mix asphalt concrete (< 50 mm) on a granular base
- intermediate hot mix asphalt concrete (50-120 mm) on a granular base
- thick hot mix asphalt concrete (> 120 mm)
- thin hot mix asphalt concrete on a chemically stabilized base or subbase
- thin hot mix asphalt on an asphalted bound base [1, 2, 4, 6].

Stabilization of the subgrade layer can apply to any of the above pavement types. Typical stabilizers include asphalt cement (for base only), lime, fly ash, or lime-fly ash combinations.

**2.** Specific and accurate information is needed for effective decisions regarding pavement design. The information will also be included in the pavement design report. These required data are as follows::

- loads
- landing gear type and geometry
- tire pressure

- traffic volume
- material characterization
- drainage characteristics.

**Load.** The pavement design method is based on the gross weight of the aircraft. For design purposes the pavement should be designed for the maximum anticipated takeoff weight of the aircraft. The design procedure assumes 95 percent of the gross weight is carried by the main landing gears and 5 percent is carried by the nose gear. Use of the maximum anticipated takeoff weight is recommended and is justified by the fact that changes in operational use can often occur and recognition of the fact that forecast traffic is approximate at best.

**Landing gear type and geometry.** The gear type and configuration dictate how the aircraft weight is distributed to the pavement and determine pavement response to aircraft loadings. Examination of gear configuration, tire contact areas, and tire pressure in common use indicated that these follow a definite trend related to aircraft gross weight. These assumed data are as follows:

1) **Single gear aircraft.** No special assumptions needed.

2) **Dual gear aircraft.** A study of the spacing between dual wheels for these aircraft indicated that a dimension of 0.51 m between the centerline of the tires appeared reasonable for the lighter aircraft and a dimension of 0.86 m between the centerline of the tires appeared reasonable for the heavier aircraft.

**3) Dual tandem gear aircraft.** The study indicated a dual wheel spacing of 0.51m and a tandem spacing of 1.14 m for lighter aircraft, and a dual wheel spacing of 0.76 m and a tandem spacing of 1.40 m for the heavier aircraft are appropriate design values.

**4) Wide body aircraft.** Wide body aircraft; i.e., B-747, DC-10 and A380 represent a radical departure from the geometry assumed for dual tandem aircraft. Due to the large differences in gross weights and gear geometries, separate design curves have been prepared for the wide body aircraft.

**Tire pressure.** Tire pressure varies between 500 to 1250 kPa depending on gear configuration and gross weight. It should be noted that tire pressure asserts less influence on pavement stresses as gross weight increases, and the assumed maximum of 1250 kPa may be safely exceeded if other parameters are not exceeded and a high stability surface course is used.

**Traffic volume.** Forecasts of annual departures by aircraft type are needed for pavement design. Information on aircraft operations is available from Airport Master Plans.

## Lecture #4.3

## Rigid Pavement Design

Plan

1. Types of rigid pavements.
2. Jointing of concrete pavements.

**1.** Rigid pavements for airports are composed of Portland cement concrete placed on a granular or treated subbase course that is supported on a compacted subgrade.

There are different types of airport rigid pavements that have been built. They resist traffic loads through flexure of the concrete. If reinforcement is used, it is used for crack control and not to carry load. Different types of pavements use joints, reinforcing steel, or both.

The term "conventional concrete pavements" is generally taken to mean either jointed plain, jointed reinforced or continuously reinforced concrete pavements but not other types. Design and detailing of joints is important for these pavements. All three conventional pavement types are used as overlays. Prestressed and precast concrete pavements are used for similar applications as conventional concrete pavements, but are used infrequently.

*Jointed plain concrete pavement* consists of unreinforced concrete slabs 5-7,5 m in length with transverse contraction joints between the slabs. The joints are spaced closely enough together so that cracks should not form in the slabs until late in the life of the pavement. Jointed plain concrete pavement is illustrated in fig. 4.5 [1, 2, 4, 11].

One important performance issue with jointed plain concrete pavement is load transfer across the joints. If joints become faulted, then drivers encounter bumps at the joints and experience a rough ride.

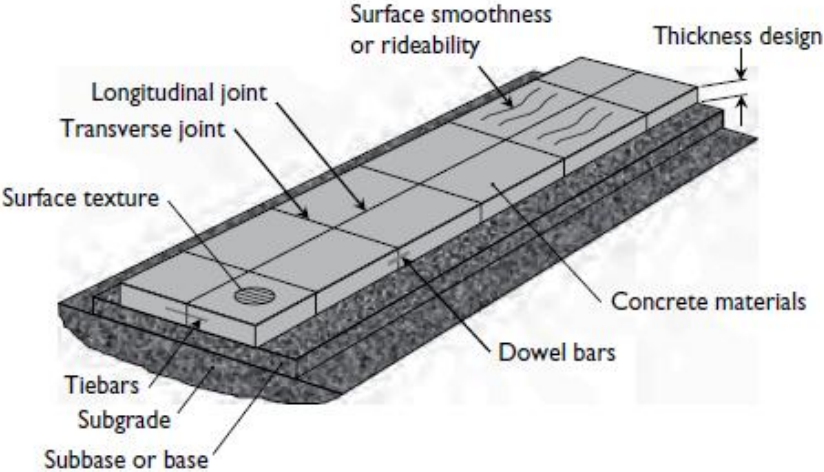



Fig. 4.5. Jointed plain concrete pavement

Two methods are used to provide load transfer across jointed plain concrete pavement joints – aggregate interlock and dowels. Aggregate interlock joints are formed during construction by sawing 1/4−1/3 of the way through the pavement to create a plane of weakness (Figure 4.6).


Fig. 4.6. Aggregate interlock joints

When the pavement carries heavy vehicle traffic aggregate interlock will break down over time and will not prevent faulting over the life of the pavement. In this case, dowels are provided across the joint for load transfer. Dowels are smooth rods, generally plainor epoxy-coated steel, which are usually oiled on side to allow the joints to open and close without resistance (fig. 4.7).

Fig. 4.7. Dowels

*Jointed reinforced concrete pavement* is distinguished from jointed plain concrete pavement by longer slabs and light reinforcement in the slabs. This light reinforcement is often termed temperature steel. Jointed reinforced concrete pavement slab lengths typically range from 7.5 to 9 m, although slab lengths up to 30 m have been used. With these slab lengths, the joints must be doweled. The slab steel content is typically in the range of 0.10–0.25 percent of the cross-sectional area, in the longitudinal direction, with less steel in the transverse direction. Because the steel is placed at the neutral axis or midpoint of the slab, it has no effect on the flexural performance of the concrete and serves only to keep cracks together. Jointed reinforced concrete pavement is illustrated in Figure 4.8 [1, 2, 4, 11].

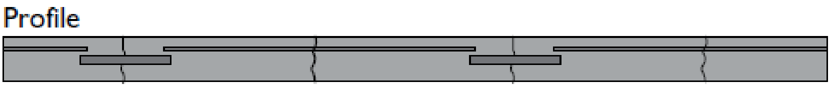



Fig. 4.8. Jointed reinforced concrete pavement

*Continuously reinforced concrete pavement* is characterized by heavy steel reinforcement and an absence of joints. Much more steel is used for continuously reinforced concrete pavement than for jointed reinforced concrete pavement, typically on the order of 0.4–0.8 percent by volume in the longitudinal direction. Steel in the transverse direction is provided in a lower percentage as temperature steel. Continuously reinforced concrete pavement is illustrated in fig. 4.9 [1, 2, 4, 11].

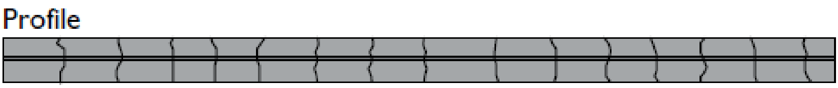



Fig. 4.9. Continuously reinforced concrete pavement

**2.** Variations in temperature and moisture content can cause volume changes and slab warping resulting in significant stresses. In order to reduce the detrimental effects of these stresses and to minimize random cracking, it is necessary to divide the pavement into a series of slabs of predetermined dimensions by means of joints. These slabs should be as nearly square as possible when no embedded steel is used.

Conventional pavements make use of several types of transverse and longitudinal joints.

Pavement joints are categorized according to the function that the joint is intended to perform. The categories are isolation, contraction, and construction joints. All joints, regardless of type, should be finished in a manner that permits the joint to be sealed. Pavement joint details are shown in fig. 4.10-4.12. These various joints are described as follows:

- **Isolation Joints**. The function of isolation joints is to isolate intersecting pavements and to isolate structures from the pavement. Isolation joints are used when conditions preclude the use of load transfer devices that span across the joint, such as where the pavement abuts a structure or where horizontal differences in movement of the pavements may occur. These joints are formed by increasing the thickness of the pavement along the edge of the slab. No dowel bars are provided (fig. 4.10).

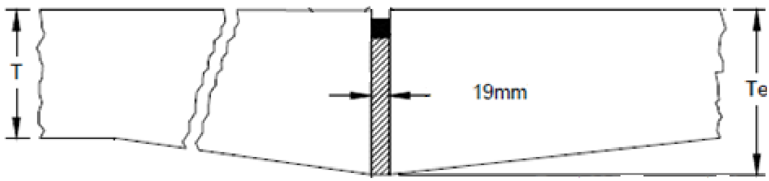



Fig. 4.10. Isolation joint

- **Contraction Joints**. The function of contraction joints is to provide controlled cracking of the pavement when the pavement contracts due to decrease in moisture content or a temperature drop. Contraction joints also decrease stresses caused by slab warping. Details for contraction joints are shown as in fig. 4.11.

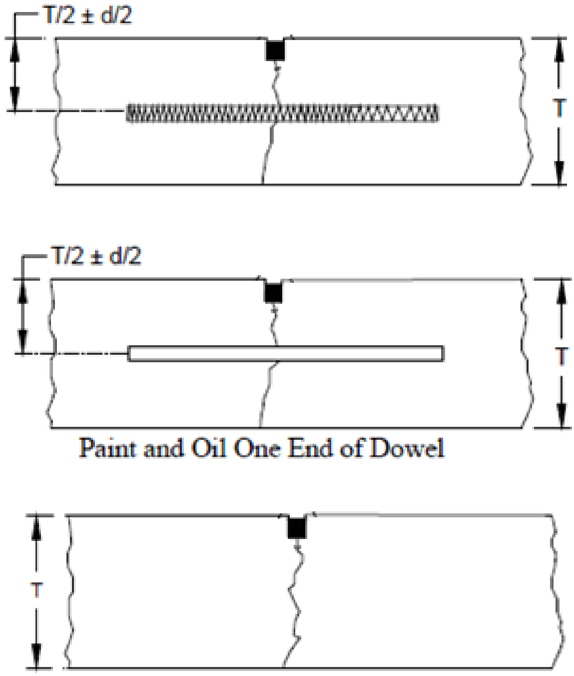



Fig. 4.11. Contraction joints

- **Construction Joints**. Construction joints are required when two abutting slabs are placed at different times, such as at the end of a day’s placement or between paving lanes (fig. 4.12) [1, 2, 4, 14].

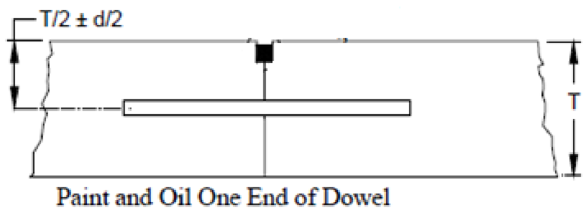



Fig. 4.12. Construction joint

The alignment and elevation of dowels is extremely important in obtaining a satisfactory joint. Transverse dowels will require the use of a fixture, usually a basket firmly anchored to the subbase, to hold the dowels in position. Supports on the baskets do not need to be cut. An alternate procedure for placing dowels in the transverse joint is to use a paving machine equipped with an automated dowel bar inserter.

Tie bars are used across certain longitudinal contraction joints to hold the slab faces in close contact. The tie bars themselves do not act as load transfer devices. By preventing wide opening of the joint, load transfer is provided by aggregate interlock in the crack below the groove-type joint.

## Lecture #4.4

## Rigid Pavement Design by Using FAARFIELD

For rigid pavement design, FAARFIELD (Federal Aviation Administration Rigid and Flexible Iterative Elastic Layered Design) uses the maximum horizontal stress at the bottom edge of the PCC slab as the predictor of pavement structural life. FAARFIELD provides the required thickness of the rigid pavement slab needed to support a given aircraft traffic mix over a particular subgrade/subbase [18].

FAARFIELD designs the slab thickness based on the assumption of edge loading. The gear load is located either tangent or perpendicular to the slab edge, and the larger of the two stresses, reduced by 25 percent to account for load transfer through the joint, is taken as the design stress for determining the slab thickness. The program FAARFIELD requires five groups of design input data: concrete flexural strength, subgrade modulus, design life in years, structural layer data, and aircraft mixture information. The program computes only the thickness of the concrete layer. The minimum slab thickness is six inches. Thicknesses of other layers of the rigid pavement structure must be selected by the user [18].

The required thickness of concrete pavement is related to the strength of the concrete used for construction of the pavement. For pavement design, the strength of the concrete is characterized by the flexural strength, since the primary action and failure mode of a concrete pavement are in flexure.

Although the flexural strength required for the pavement design is related to the flexural strength, the strengths used for the pavement design. Unless expedited construction requires early opening of the pavement to aircraft traffic (less than 28 days). However, the long-term strength achieved by the concrete is normally expected to be at least 5 percent more than the strength measured at 28 days.

To establish the flexural strength for the thickness design the designer needs to consider several factors, such as:

- Capability of the industry in a particular area to produce concrete at a particular strength;
- Flexural strength in cement content data from prior projects at the airport;
- The need to avoid high cement contents, which can affect concrete durability;
- Whether early opening requirements necessitate using a lower strength than 28-day.

The standard design life for pavement thickness design is 20 years. The FAARFIELD computer program is capable of considering other design life timeframes [18].

Up to three base/subbase layers can be added to the pavement structure in FAARFIELD for new rigid design. The number of subbase layers is limited because experience shows that above three layers the effect on designed slab thickness is small and does not justify the additional computation time that would be required. The layer thickness must be entered for each base/subbase layer. For standard base/subbase materials, the modulus and Poisson’s ratio are internally set and cannot be changed by the user. However, the variable stabilized and undefined layers allow the user to input directly a modulus value.

The user inputs specific information for each aircraft in the mix, including aircraft type, gross weight, number of annual departures, and percentage of annual growth.

As an airplane moves along a pavement section it seldom travels in a perfectly straight path or along the exact same path as before. This lateral movement is known as airplane wander and is modeled by a statistically normal distribution. As an airplane moves along a taxiway or runway, it may take several trips or passes along the pavement for a specific point on the pavement to receive a full-load application. The ratio of the number of passes required to apply one full load application to an unit area of the pavement is expressed by the pass-to-coverage (P/C) ratio. It is easy to observe the number of passes an airplane may make on a given pavement, but the number of coverages must be mathematically derived based upon the established P/C ratio for each airplane. By definition, one coverage occurs when a unit area of the pavement experiences the maximum stress for rigid pavement induced by a given aircraft. For rigid pavements, coverages are a measure of repetitions of the maximum stress occurring at the bottom of the PCC layer. Coverages resulting from operations of a particular aircraft type are a function of the number of aircraft passes, the number and spacing of wheels on the aircraft main landing gear, the width of the tire-contact area, and the lateral distribution of the wheel-paths relative to the pavement centerline or guideline markings. In calculating the P/C ratio, FAARFIELD uses the concept of effective tire width. For rigid pavements, the effective tire width is defined at the surface of the pavement and is equal to a nominal tire contact patch width as shown in fig. 4.13 [17].

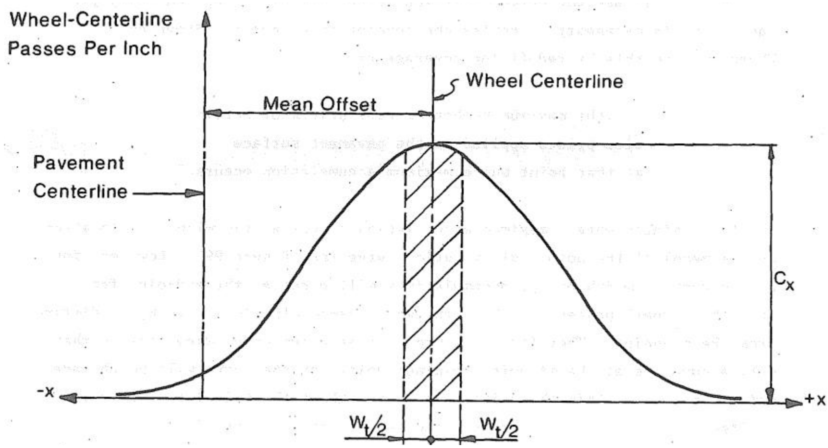



Fig. 4.13. Theoretical normal distribution for single wheel

All effective tire width and P/C ratio calculations are performed internally within the FAARFIELD program

$$PCR = \frac{1}{C_{XC} W_t},$$

where $C_{XC}$ - units of coverages per meter per aircraft pass.

$W_t$ - tire-contact width, m [14].

## Lecture #4.5

## ICAO Method of Reporting Airport Pavement Strength

Plan

1. Development of the standardized method.
2. Determination of the ACN. Subgrade category.
3. Determination of PCN numerical value.

**1.** The standardized method, known as the Aircraft Classification Number – Pavement Classification Number (ACN-PCN) method, has been developed and adopted as an international standard and has facilitated the exchange of pavement strength rating information.

In 1977, ICAO established a Study Group to develop a single international method of reporting pavement strengths. The study group developed and ICAO adopted the Aircraft Classification Number - Pavement Classification Number (ACN-PCN) method. Using this method, it is possible to express the effect of an individual aircraft on different pavements with a single unique number that varies according to aircraft weight and configuration (e.g. tire pressure, gear geometry, etc.), pavement type, and subgrade strength. This number is the Aircraft Classification Number (ACN). Conversely, the load-carrying capacity of a pavement can be expressed by a single unique number, without specifying a particular aircraft or detailed information about the pavement structure. This number is the Pavement Classification Number (PCN).

The ACN-PCN system is structured so a pavement with a particular PCN value can support, without weight restrictions, an aircraft that has an ACN value equal to or less than the pavement's PCN value. This is possible because ACN and PCN values are computed using the same technical basis [5, 15].

**2.** ACN is defined as a number that expresses the relative effect of an aircraft at a given weight on a pavement structure for a specified standard subgrade strength.

The aircraft manufacturer provides the official computation of an ACN value. Computation of the ACN requires detailed information on the operational characteristics of the aircraft such as maximum center of gravity, maximum ramp weight, wheel spacing, tire pressure, and other factors.

The ACN-PCN method adopts four standard levels of subgrade strength for rigid pavements and four levels of subgrade strength for flexible pavements. These standard support conditions are used to represent a range of subgrade conditions as shown in Tables 4.1 and 4.2.

Table 4.1. Standard Subgrade Support Conditions for Rigid Pavement ACN Calculation

| Subgrade Strength Category | Subgrade Support k-Value, MN/m$^3$ | Represents, MN/m$^3$ | Code Designation |
|---|---|---|---|
| High | 150 | k >120 | A |
| Medium | 80 | 60<k<120 | B |
| Low | 40 | 25<k<60 | C |
| Ultra Low | 20 | k<25 | D |

Table 4.2. Standard Subgrade Support Conditions for Flexible Pavement ACN Calculation

| Subgrade Strength Category | Subgrade Support CBR-Value | Represents | Code Designation |
|---|---|---|---|
| High | 15 | CBR > 13 | A |
| Medium | 10 | 8<CBR<13 | B |
| Low | 6 | 4<CBR<8 | C |
| Ultra Low | 3 | CBR<4 | D |

For rigid pavements, the aircraft landing gear floatation requirements are determined by the Westergaard solution for a loaded elastic plate on a Winkler foundation (interior load case), assuming a concrete working stress of 2.75 MPa.

For flexible pavements, aircraft landing gear floatation requirements are determined by the California Bearing Ratio (CBR) method for each subgrade support category. The CBR method employs a Boussinesq solution for stresses and displacements in a homogeneous, isotropic elastic half-space.

Using the parameters defined for each type of pavement section, a mathematically derived single wheel load is calculated to define the landing gear/pavement interaction. The derived single wheel load implies equal stress to the pavement structure and eliminates the need to specify pavement thickness for comparative purposes. This is achieved by equating the thickness derived for a given aircraft landing gear to the thickness derived for a single wheel load at a standard tire pressure of 1.25 MPa. The ACN is defined as two times the derived single wheel load (expressed in thousands of kilograms).

Because aircraft can be operated at various weight and center of gravity combinations, ICAO adopted standard operating conditions for determining ACN values. The ACN is to be determined at the weight and center of gravity combination that creates the maximum ACN value. Tire pressures are assumed to be those recommended by the manufacturer for the noted conditions. Aircraft manufacturers publish maximum weight and center of gravity information in their Aircraft Characteristics for Airport Planning (ACAP) manuals. To standardize the ACN calculation and to remove operational frequency from the relative rating scale, the ACN-PCN method specifies that ACN values should be determined at a frequency of 10,000 coverages [5, 15].

**3.** The determination of a pavement rating in terms of PCN is a process of determining the ACN for each aircraft considered to be significant to the traffic mixture operating of the subject pavement and reporting the ACN value as the PCN for the pavement structure. Under these conditions, any aircraft with an ACN equal to or less than the reported PCN value can safely operate on the pavement subject to any limitations on tire pressure.

Determination of the numerical PCN value for a particular pavement can be based upon one of two procedures: the “Using” aircraft method or the “Technical” evaluation method. ICAO procedures permit member states to determine how PCN values will be determined based upon internally developed pavement evaluation procedures. Either procedure may be used to determine a PCN, but the methodology used must be reported as part of the posted rating.

The PCN numerical value is determined from an allowable load rating. While it is important not to confuse the PCN value with a pavement design parameter, the PCN is developed in a similar fashion. An allowable load rating is determined by applying the same principles as those used for pavement design. The process for determining the allowable load rating takes factors such as frequency of operations and permissible stress levels into account. Allowable load ratings are often discussed in terms of aircraft gear type and maximum gross aircraft weight, as these variables are used in the pavement design procedure. Missing from the allowable load rating, but just as important, is frequency of operation. In determining an allowable load rating, the evaluation must address whether the allowable load rating represents the pavement strength over a reasonable frequency of operation. Once the allowable load rating is established, the determination of the PCN value is a simple process of determining the ACN of the aircraft representing the allowable load and reporting the value as the PCN [5, 15].

## Lecture #4.6

## Pavement Distresses

Plan

1. Types of pavement distress.
2. Rigid pavement distresses.
3. Flexible pavement distresses.

**1.** Pavement distress types are:

a. cracking;
b. distortion;
c. disintegration;
d. loss of skid resistance.

Cracks may occur in concrete pavements due to a one time overload or due to repeated fatigue loading.

Cracks in flexible pavements are caused by deflection of the surface over an unstable foundation, shrinkage of the surface, thermal expansion and contraction of the surface, poorly constructed lane joints, or reflection cracking.

Distortion refers to a change in the pavement surface original position, and it results from foundation settlement, expansive soils, frost-susceptible soils, or loss of fines through improperly designed subdrains or drainage systems.

Distortion in flexible pavements is caused by foundation settlement, insufficient compaction of the pavement courses, lack of stability in the bituminous mix, poor bond between the surface and the underlying layer of the pavement structure, and swelling soils or frost action in the subgrade.

Disintegration is the breaking up of a pavement into small, loose particles and includes the dislodging of aggregate particles. Improper curing and finishing of the concrete, unsuitable aggregates and improper mixing of the concrete can cause this distress.

Disintegration in a flexible pavement is caused by insufficient compaction of the surface, insufficient asphalt in the mix, loss of adhesion between the asphalt coating and aggregate particles, or overheating of the mix.

Skid resistance refers to the ability of a pavement to provide a surface with the desired friction characteristics under all weather conditions. It is a function of the surface texture or the buildup of contaminants.

Factors that decrease the skid resistance of a pavement surface and can lead to hydroplaning include too much asphalt in the bituminous mix, poor aggregate subject to wear, and buildup of contaminants [11,16].

**2.** Several different types of cracking can occur:

- longitudinal, transverse cracks (fig. 4.14-4.15);

Fig. 4.14. Longitudinal crack

Fig. 4.15. Transverse crack

- corner breaks **(**load repetition, combined with loss of support and curling stresses, usually causes cracks at the slab corner) (fig. 4.16);

Fig. 4.16. Corner breaks

- durability "D" cracking **(**it is caused by the concrete's inability to withstand environmental factors such as freeze-thaw) (fig. 4.17);

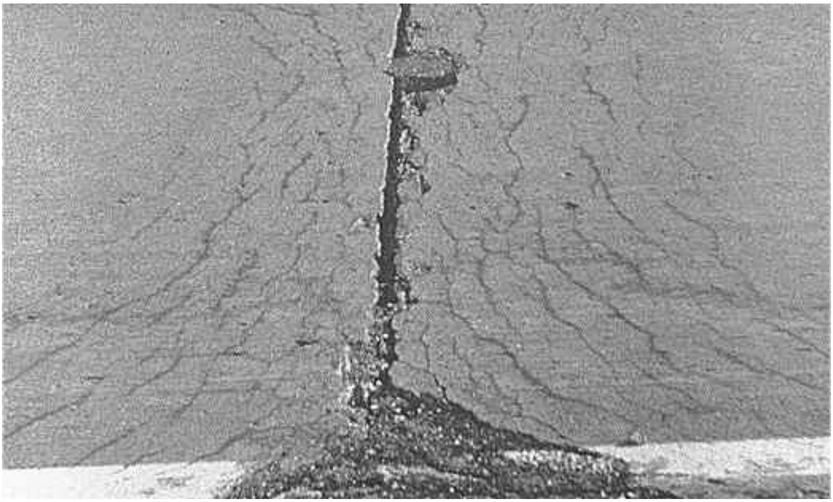


Fig. 4.17. Durability “D” cracking

- joint seal damage **(**joint seal damage is any condition that enables soil or rocks to accumulate in the joints or that allows infiltration of water) (fig. 4.18);

- shattered slab **(**this is caused by overloading and/or inadequate foundation support) (fig. 4.19).

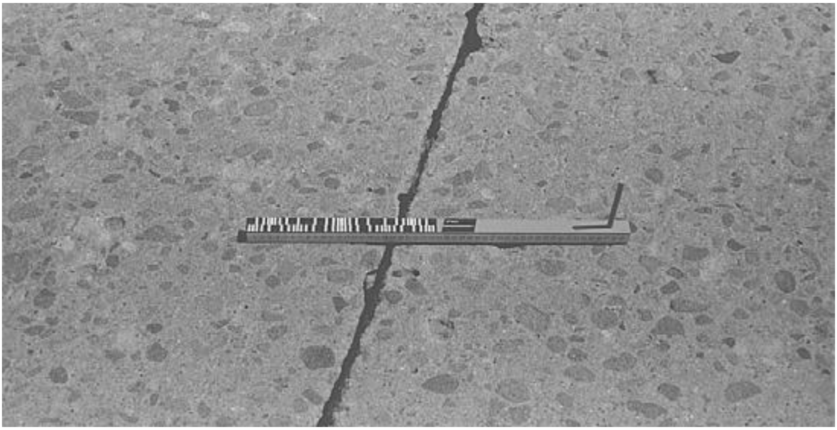


Fig. 4.18. Joint seal damage

Fig. 4.19. Shattered slab condition

Disintegration falls into four categories:
- scaling, map cracking (fig. 4.20, 4.21);

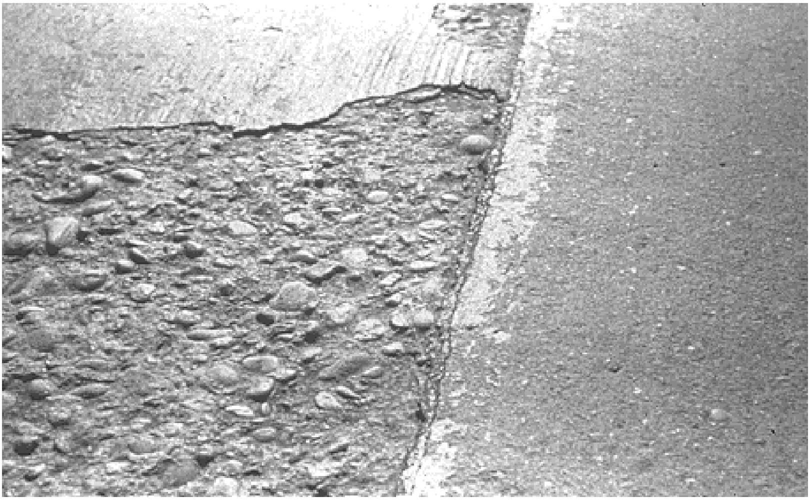


Fig. 4.20. Scaling

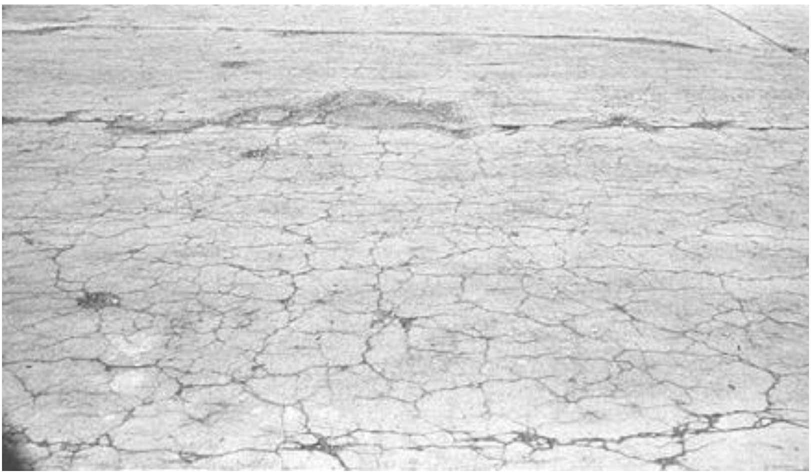


Fig. 4.21. Map cracking

- joint spalling (spalling is caused by excessive stresses at the joint or crack caused by infiltration of incompressible materials or traffic loads combined with traffic loads) (fig. 4.22);

- corner spalling (corner spalling is the raveling or breakdown of the slab within 0,5 meter of the corner) (fig. 4.23);

- blowups (blowups occur in hot weather) (fig. 4.24) [11, 16].

Fig. 4.22. Joint spalling at a transverse joint

Fig. 4.23. Corner spalling

Fig. 4.24. Blowup in a pavement

Two types of distortion generally occur:

- pumping (the deflection of the slab when loaded may cause pumping, which is characterized by the ejection of water and subgrade (or subbase) material through the joints or cracks in a pavement) (fig. 4.25);

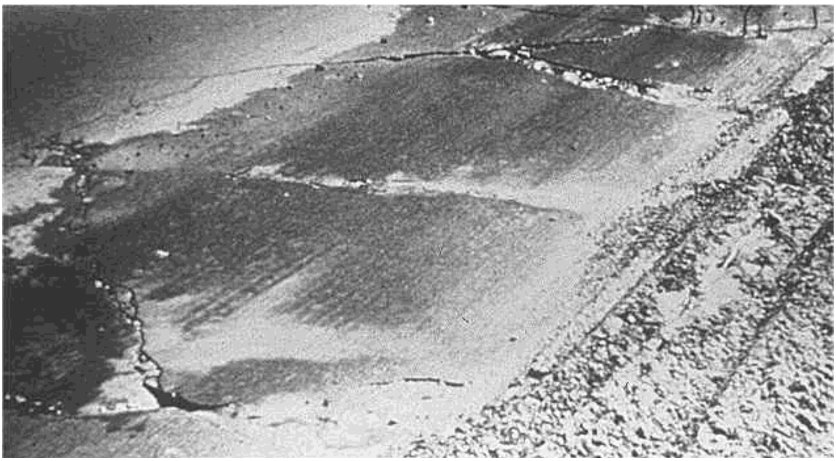


Fig. 4.25. Pumping

- settlement or faulting (this condition may result from frost heave, loss of load transfer device or swelling soils) (fig. 4.26).

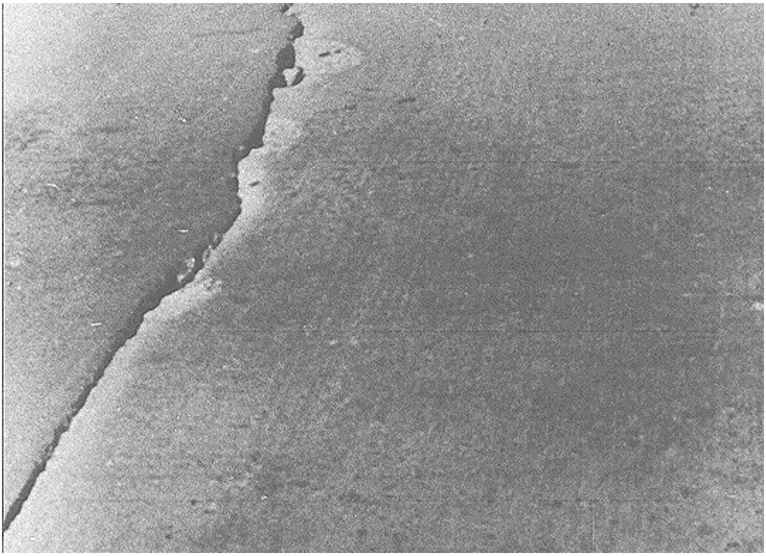


Fig. 4.26. Settlement or faulting

Types of skid resistance are:

- polished aggregates (aggregate polishing is caused by repeated traffic applications) (fig. 4.27).

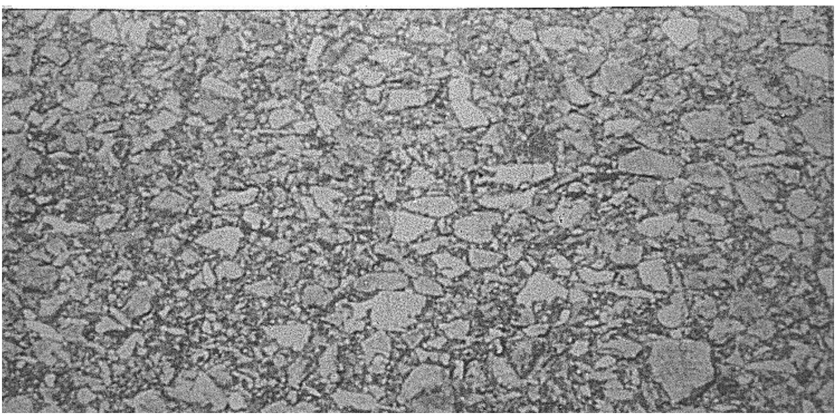
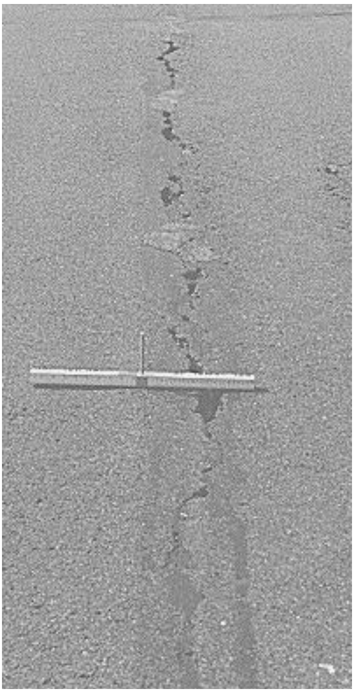


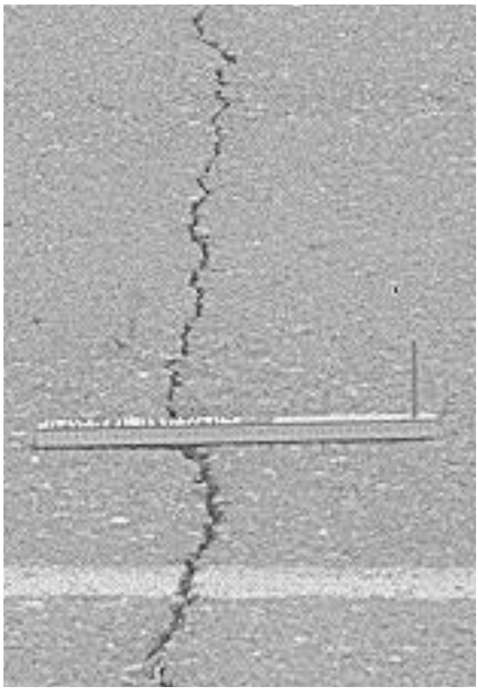
Fig. 4.27. Polished aggregate

**3.** Five types of cracks commonly occur in flexible pavements:

- longitudinal and transverse cracks (fig. 4.28);
- alligator or fatigue cracking (they may be caused by fatigue failure of the bituminous surface under repeated loading or by excessive deflection of the asphalt surface over under-designed foundation) (fig. 4.29);
- block cracking (fig. 4.30);
- slippage cracks (they usually occur when there is a low-strength surface mix or poor bond between the surface and the next layer of the pavement structure) (fig. 4.31);
- reflection cracking (they occur most frequently in asphalt overlays on Portland cement concrete pavements) (fig. 4.32) [11, 16].



a



b

Fig. 4.28. Longitudinal (a) and transverse (b) cracks

Fig. 4.29. Alligator fatigue cracking

Fig. 4.30. Block cracking

Fig. 4.31. Slippage cracking

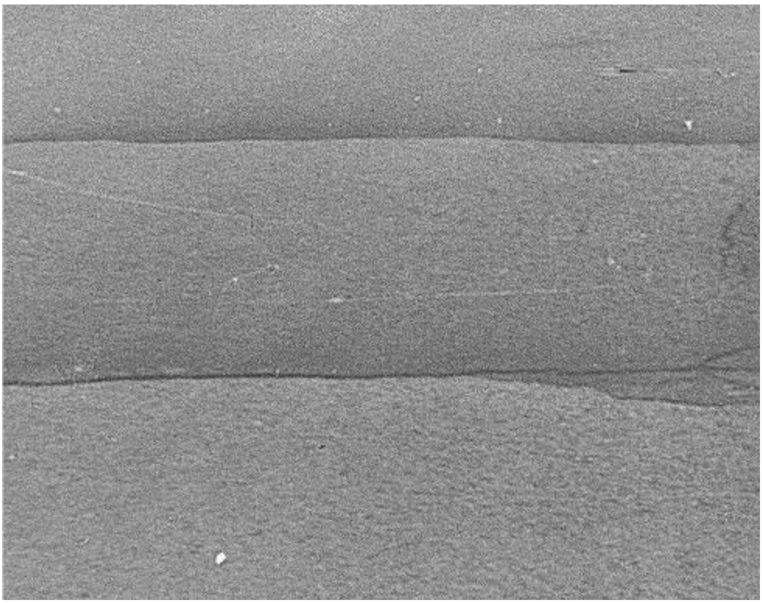


Fig. 4.32. Joint reflection cracking from PCC

The most common type of disintegration in bituminous pavements is raveling (fig. 4.33). Raveling is the wearing away of the pavement surface caused by the dislodging of aggregate particles and the loss of asphalt binder.

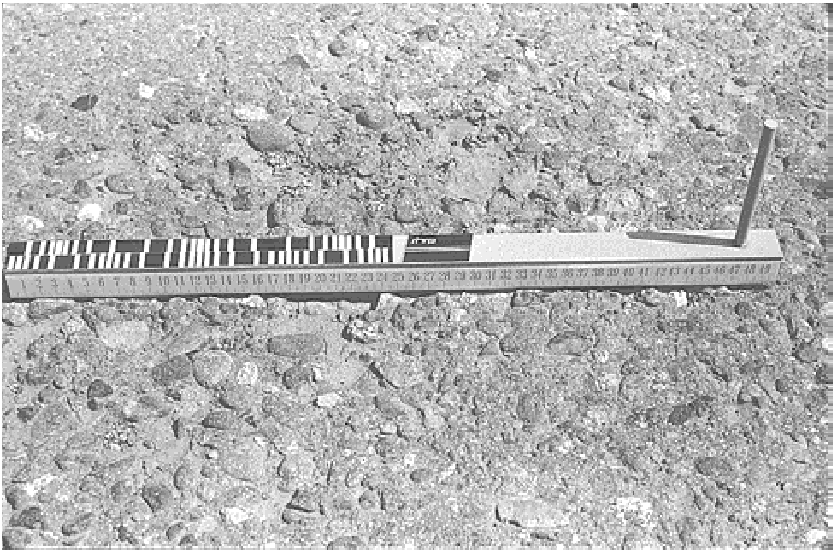


Fig. 4.33. Raveling

Four types of distortion commonly occur:

- rutting (a rut is characterized by a surface depression in the wheel path; this type of distress is caused by a permanent deformation in any one of the pavement layers or subgrade, resulting from the consolidation or displacement of the materials due to traffic loads) (fig. 4.34);
- shoving (shoving is a form of plastic movement resulting in localized bulging of the pavement surface; shoving can be caused by a lack of stability in the mix and a poor bond between material layers) (fig. 4.35);
- depression (depressions are localized low areas of limited size; depressions may result from traffic heavier than that for which the pavement was designed) (fig. 4.36);

- swelling (it may occur sharply over a small area or as a longer gradual wave; a swell is usually caused by frost action in the subgrade or by swelling soil) [11, 16].

Fig. 4.34. Rutting in a pavement

Figure 4.35. Shoving

Fig. 4.36. Depression in a pavement

In bituminous pavements, a loss of skid resistance may result from the following:

- bleeding (bleeding is a film of bituminous material on the pavement surface that usually becomes quite sticky; it occurs when asphalt fills the voids of the mix during hot weather, then expands out onto the surface) (fig. 4.37);

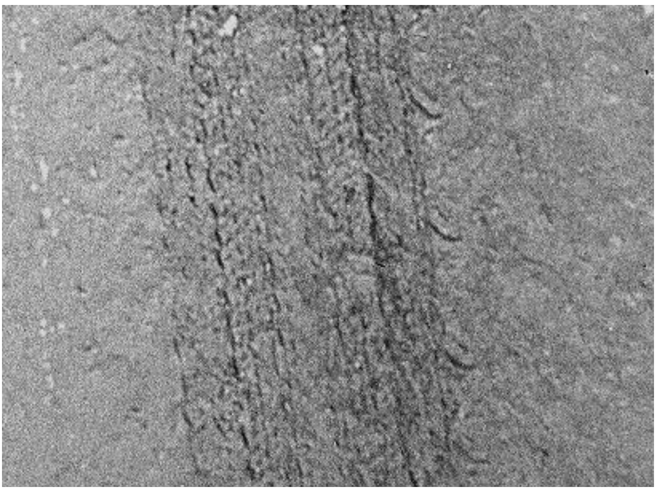


Fig. 4.37. Tire marks evident in bleeding

- polished aggregate (aggregate polishing is caused by repeated traffic applications; it occurs when the aggregate extending above the asphalt is either very small, of poor quality, or contains no rough or angular particles to provide good skid resistance) (fig. 4.38).

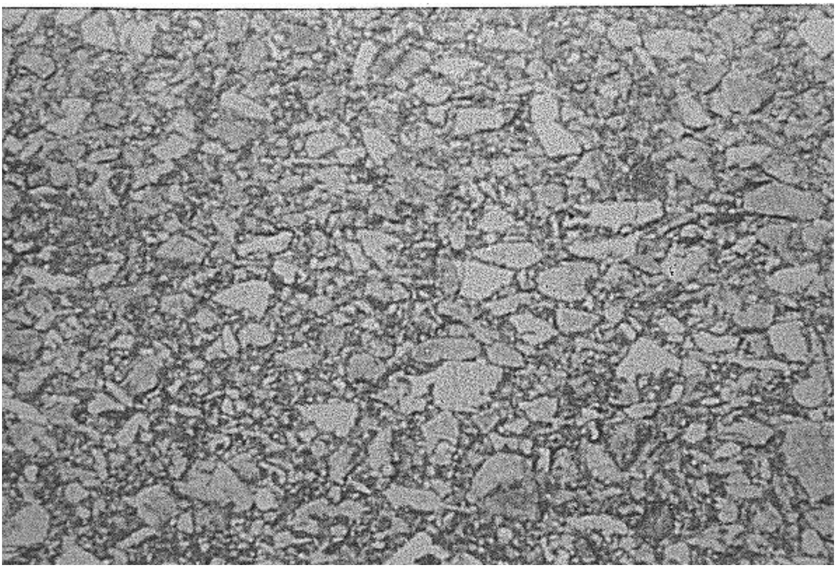


Fig. 4.38. Polished aggregate

## Control questions to Module #4

1. What is the function of airport pavements?
2. What pavement courses do you know?
3. What types of flexible and rigid pavements do you know?
4. What does ACN mean?
5. What does PCN mean?
6. How many ICAO subgrade categories do you know?
7. What methods used to determine PCN do you know?
8. What concrete pavement distresses do you know?
9. What bituminous pavement distresses do you know?
10. Information needed for pavement design.
11. ICAO method of reporting airport pavement strength.

## SUMMARY

Airports are complex businesses with functions that extend substantially beyond the airfield or "traffic" side of operations. As airports increase in size in terms of passenger throughput, the non-aviation revenues become increasingly important. It is also clear that in most countries, airports maintain economic viability by developing a broadly based revenue capability.

The air transport industry continues to expand in response to increasing dependence on fast, effective means of transportation. Experience in planning, design, airport engineering, implementation and maintenance of the aviation infrastructure helps to meet the demands.

The analysis of the cargo market is similar in basic method and in the variable which generate traffic. Factors affecting cargo growth are such as continuing increased share of integrated carriers, and time and cost sensitive products. Market demands, possible obsolescence of stock, cost of inventory, the necessary lead time in placing orders for surface shipments, and the possibility of reduction of warehouse expenses are all factors that may influence the shipper acceptance of a rate level for an air shipment.

The technical forecasting of passenger travel usually involves an urban transportation planning model, requiring the estimation of trip generation, trip distribution, and route assignment. Passenger trips are the focus of transport engineering because they often represent the peak of demand on any transportation system. Therefore, the design aspects of airport engineering include the sizing of transportation facilities, determining the materials and thickness used in pavement, designing the geometry of the roadway. Newer technologies involve intelligent transportation systems, advanced traffic control systems, and vehicle infrastructure integration.

Thus, on a long term basis the international aviation sector is a growth sector, supporting economic and social growth all over the world. The overall international growth for the last 10 years has amounted to 4,8% per year with an even stronger growth rate in the emerging markets, particularly in Central Europe and in Asia. The general forecast for the next 20 years foresees an annual growth rate of 5.2%. This international growth presents challenges and opportunities for improvement.

Airport pavements and structures such as culverts and bridges are usually designed to last for the foreseeable future of the airport. Information concerning the landing gear arrangement of future heavy aircraft is speculative. It may be assumed with sufficient confidence that strengthening of pavements to accommodate future aircraft can be performed without undue problems. Strengthening of structures, however, may prove to be extremely difficult, costly, and time-consuming. Point loadings on some structures may be increased; while on overpasses, the entire aircraft weight may be imposed on a deck span, pier or footing.

Multi layer linear elastic systems have been used for many years for the design of airfield pavements and the analysis of the damaging effect of complex multiple wheel configurations. Normally the peak tensile strain at the bottom of the asphalt layer is taken as one of the design criteria and the number of peak strain repetitions is used as input for a fatigue analysis. The problem with this approach is that with multiple wheel configurations it is not clear whether one should take into account the number of strain peaks as number of load repetitions or the number of gear passes. Another problem with such analyses is that pavement materials are certainly not linear elastic, they are non linear elasto-visco-plastic. This behavior should be taken into account especially since tomorrow heavy aircraft will generate high stresses and strains in the pavement layers.

## REFERENCES


1. *Ашфорд Н.* Проектирование аэропортов / Ашфорд Н., Райт П. — М. : Транспорт, 1988. — 310 с.
2. Аэродромы гражданской авиации / [Блохин В. И., Белинский И. А., Циприанович И. В., Билеуш А. И.]. — М. : Воздушный транспорт, 1996. — 400 с.
3. Викторов Б. И. Наземные сооружения аэропортов / Викторов Б. И. — М. : Транспорт, 1991. — 347 с.
4. Аэродромные покрытия. Современный взгляд / [Кульчицкий В. А., Макагонов В. А., Васильев Н. Б. и др.]. — М. : Физико-математическая литература, 2002. — 528 с.
5. Руководство по проектированию аэродромов. Часть 3. Покрытия // Рекомендации Международной организации гражданской авиации (ИКАО). Doc №9184. — 1983. — 348 с.
6. СНиП 2.05.08-85. Аэродромы. — М. : ЦИТП Госстроя СССР, 1985. — 59 с.
7. *Юркин Ю. А.* Аэродромы и аэропорты: учебное пособие / Юркин Ю. А. — М. : МГТУ ГА, 2000. — 104 с.
8. Advisory Circular London 150/5070-6A. Airport Master Plans (6-85), US Department of Transportation, Federal Aviation Administration, Washington, DC, 1985.
9. Airport Planning Manual, Part 1, Master Planning // 2nd ed. International Civil Aviation Organisation, Montreal. — 1987.
10. IATA (2004): Airport Development Reference Manual, 9th ed. International Air Transport Association, Montreal-Geneva. — 2004.
11. *Norbert Delatte* Concrete pavement design, construction and performance / Norbert Delatte. — New York: Taylor & Francis, 2008. — 389 p.
12. *Odoni, A. R., de Neufville, R.* Passenger terminal design // Transpn. Res. A. — Vol. 26A, No. 1. — 1992. — pp. 27-35.
13. *Oliver, J.* Guiding light // Passenger Terminal World, Oct. — 1999. — pp. 65-69.
14. Advisory Circular 150/5320-6E. Airport Pavement Design and Evaluation [Електронний ресурс], US Department of Transportation, Federal Aviation Administration, 2008. — 122 p. — (Draft / US Department of Transportation, Federal Aviation Administration). — Режим доступу: http://www.faa.gov/airports_airtraffic/airports/resources/draft_advisory_circulars/media/draft_150_5320_6E.pdf
15. Advisory Circular 150/5335-5b. Standardized Method of Reporting Airport Pavement Strength - PCN, US Department of Transportation, Federal Aviation

Administration, 2008. — 77 p. — (Draft / US Department of Transportation, Federal Aviation Administration).
16. DOT/FAA/AR-04/46. Operational Life of Airport Pavements [Електронний ресурс], US Department of Transportation, Federal Aviation Administration, 2004. — 117 p. — Режим доступу: http://www.airporttech.tc.faa.gov/NAPTF/Download/Operational%20Life.pdf
17. Field Survey and Analysis of Aircraft Distribution on Airport Pavements. Report No. FAA-RD-74-36 [Електронний ресурс] / Victor A. HoSang. — Washington : Systems Research and Development Service Airport Division, 1975. — 286 p. — Режим доступу: http://www.airporttech.tc.faa.gov/Pavement/Downloads/rd74-36.pdf
18. FAARFIELD – New FAA Airport Thickness Design Software [Електронний ресурс] / Izydor Kawa, David R. Brill, Gordon F. Hayhoe // 2007 FAA Worldwide Airport Technology Transfer Conference. Atlantic City, New Jersey, April, 2007. — Atlantic City, 2007. — 15 p. — Режим доступу: http://www.airporttech.tc.faa.gov/naptf/att07/2007/Papers/P07077%20Kawa%20et%20al.pdf

Навчальне видання

Родченко Олександр Васильович
Гирич Вікторія Юріївна

# ПРОЕКТУВАННЯ АЕРОПОРТІВ

Lecture course

Редактор
Коректор
Технічний редактор

Підп. до друку __.__.11 Формат 60х84/16. Папір офс.
Офс. друк. Ум.друк.арк. _,__. Обл.-вид. арк. _,__.
Тираж 60 пр. Замовлення №___-_. Вид.№ ___/_.

Видавництво НАУ
03058, Київ-58, проспект Космонавта Комарова, 1.

Свідоцтво про внесення до Державного реєстру ДК
№ 977 від 05.07.2002