Transportation Engineering

Course Code –CE-422

Contact Hours -3+3

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Terminal

- In airport system, the terminal performs the unique function of serving as a link between airside and groundside for passengers.
- Provide and orderly and convenient process by which the passenger from his automobile or public transportation proceed to aircraft.

Basic Factor for Terminal Design

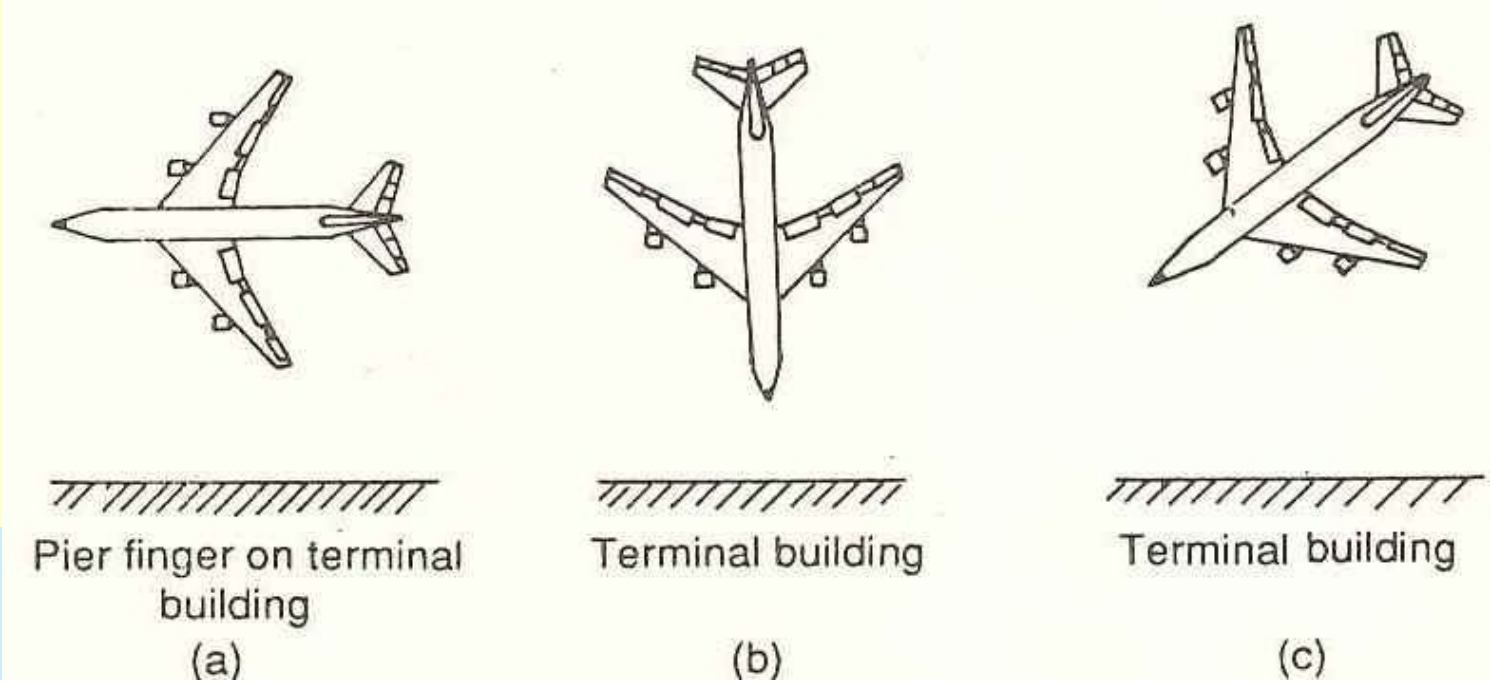
- Apron- Gate System
  - Number of Gates
  - Apron and ramp area
- Aircraft parking arrangement
  - Parallel to building
  - Perpendicular/ Inclined at an angle
- Shortest walking distance from vehicle to aircraft

Basic Factor for Terminal Design

- Orientation of travelling public approaching the terminal
- Minimum level change for passenger within the terminal
- Avoidance of passengers cross flows
- Shortest possible distance of passengers and their baggage to the parking or public transportation
- Compatibility of all facilities with existing and future generation.

Parking Arrangement

- Parking of an aircraft with respect to the terminal can be either parallel to the terminal building or be in the nose-dive in position.
- Nose dive in position beneficial in case of boarding devices like aerobridges



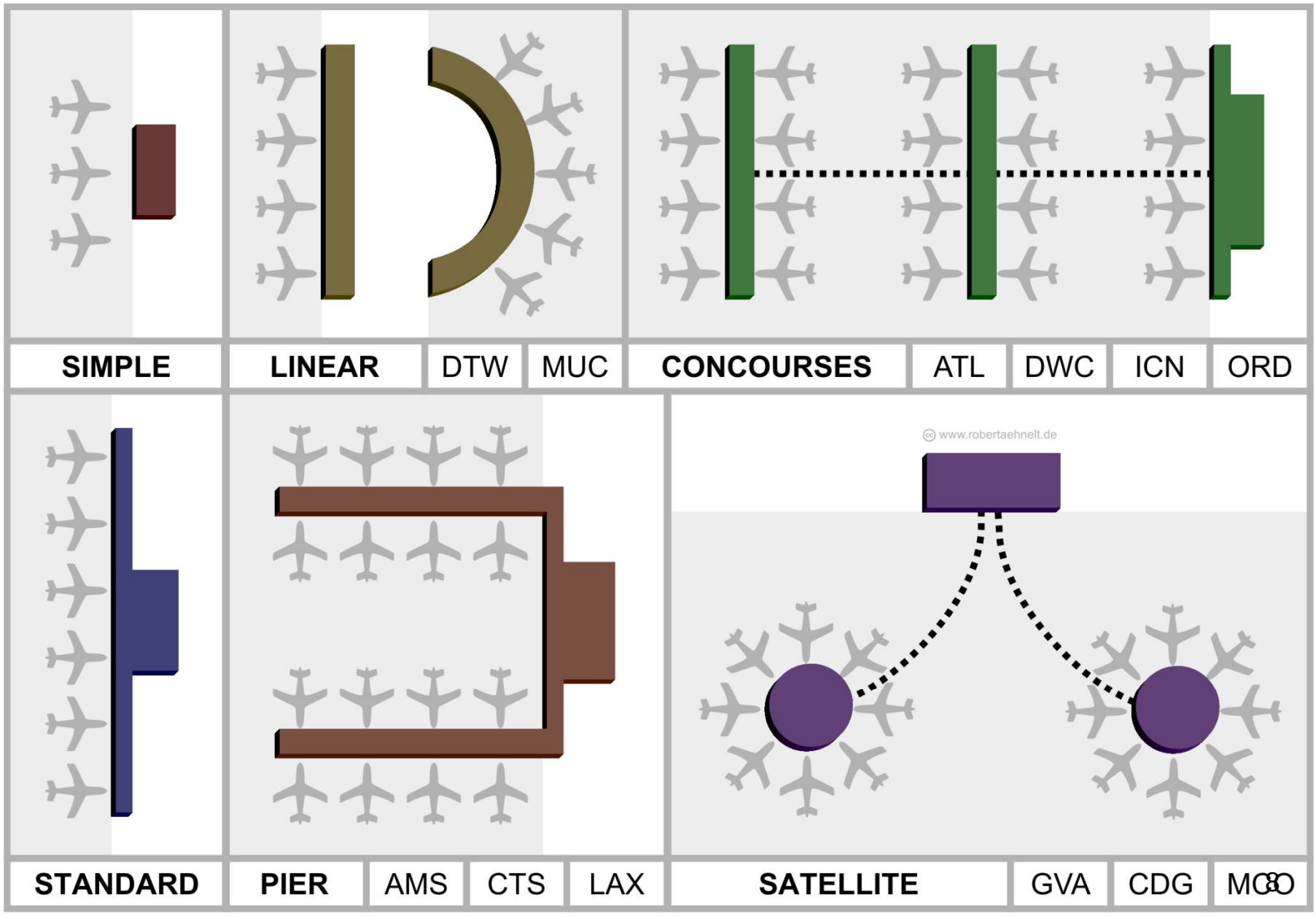
Types of Terminal

- Centralized Terminal
  - Allows passenger and baggage to proceed in one building
  - Common Hall- housing of facilities
  - Allows maximum use of facilities and equipment in the central area along with customs and security
    - Pier finger
    - Transport concept
    - Satellite Concept

Types of Terminal (cont'd)

- Semi Centralized Processing
  - Each airline or several airlines combined may be located in a separate terminal building
  - Each building has direct access to ground transportation
  - Modules added as need arises
    - Linear Concept
    - Unit Terminal Concept

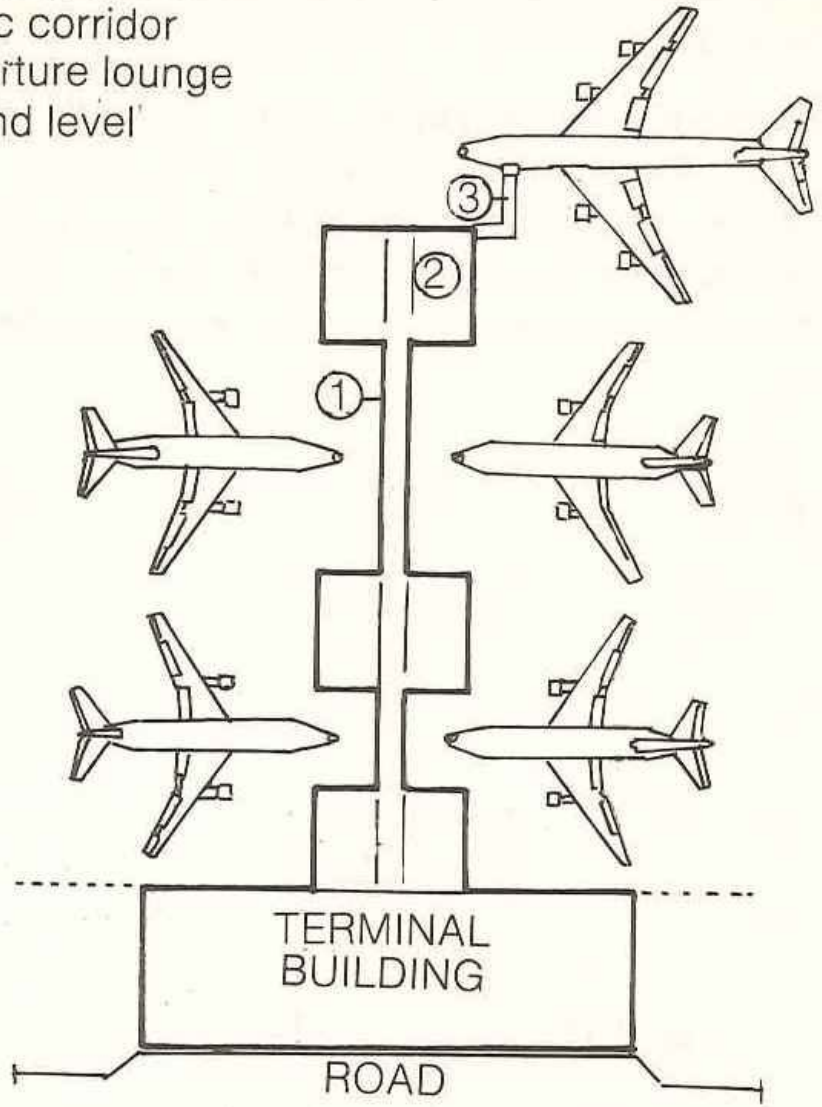
TERMINAL CONFIGURATIONS

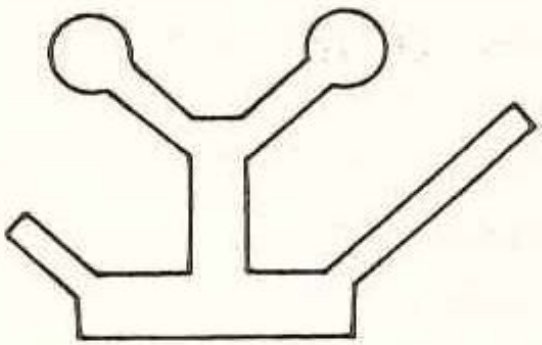


Pier Finger Concept- Centralized Terminal

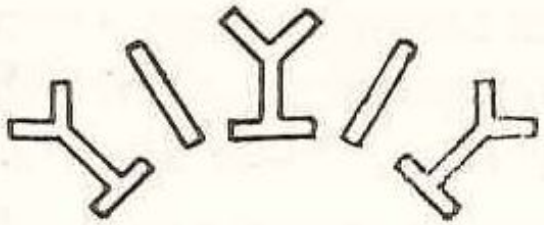
- All passenger and baggage are directed to one terminal building
- Departing passenger are processed at central check in area and walk to respective gates
- Baggage collected at a central check in counter and sorted for different aircrafts
- Arriving passengers and their baggage are processed in the reverse flow

1. Boarding device
2. Public corridor
3. Departure lounge second level





Frankfurt/main



Chicago/O'Hare

Fig. 5.18 *Types of airport terminals: (a) Pier concept*

Advantages of Pier Finger

- Centralization of airline and governmental authority staff
- Permits use of relatively simple flight information display system.
- Facilitates control of passengers if required.

Disadvantages

- Long walking distance
- Curbside congestion in peak hours

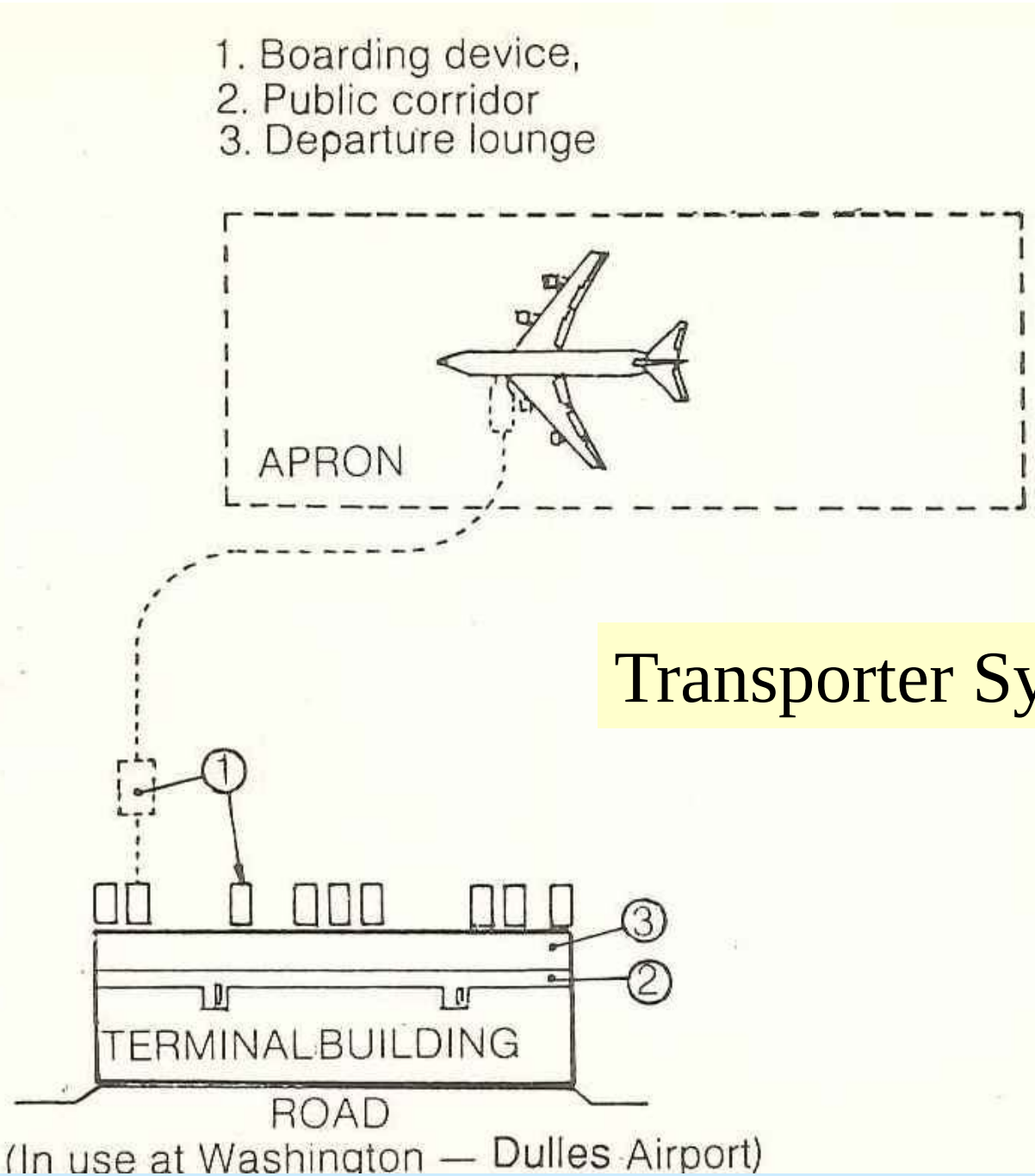
Disadvantages of Pier Finger

- Limited expansion capabilities of main terminal due to complex building geometry
- Limited compatibility with future larger aircraft design development
- Separation of arriving/ departing passengers at different level.
- High operating/ maintenance costs for baggage conveying or sorting system
- Potential of baggage mishandling

Transporter/ Satellite Concept

- Transporter System
  - Aircraft parked away from the terminal area.
  - Passenger and baggage are transported by mobile lounge to and from aircraft.
  - Departing passengers are processed at central area.
  - Arriving passengers are processed in reciprocal flow system.

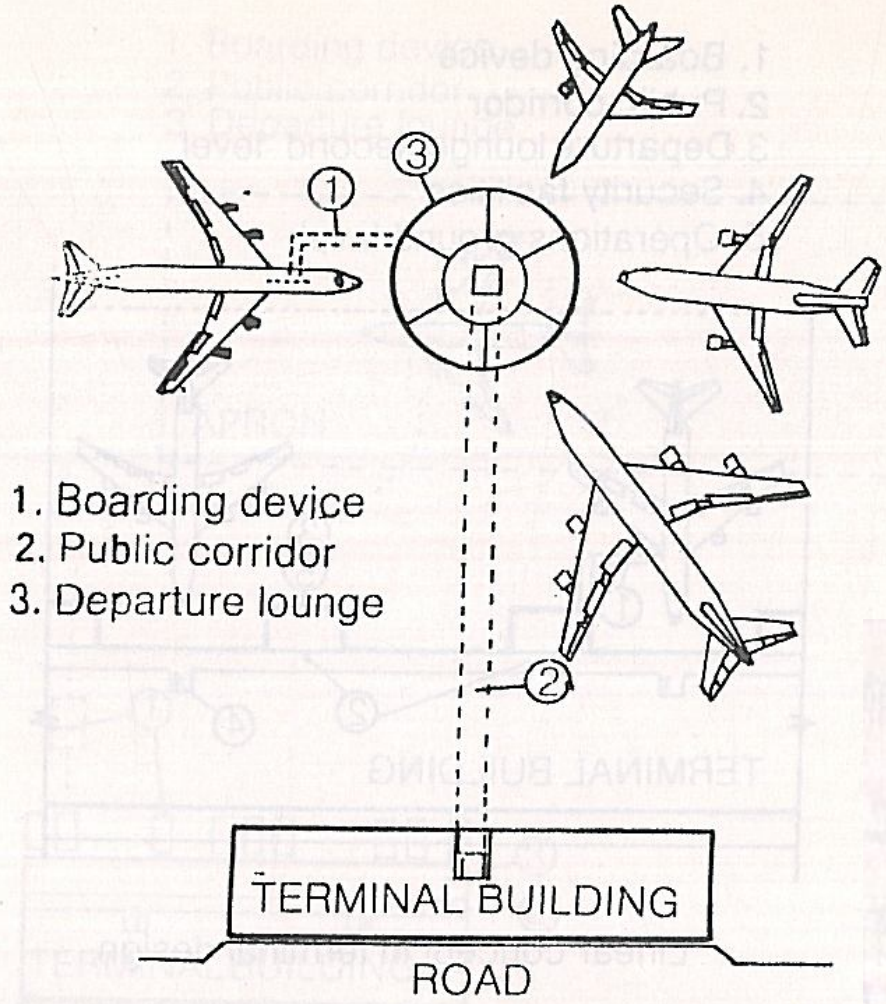
Transporter System

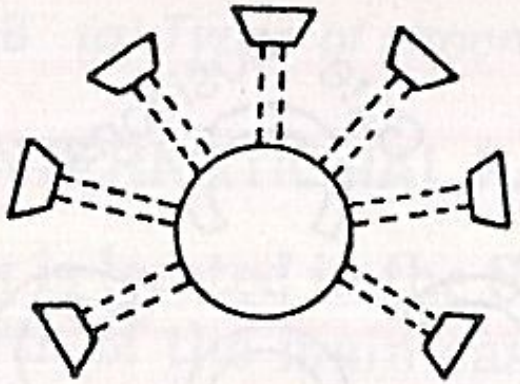


(In use at Washington — Dulles Airport)

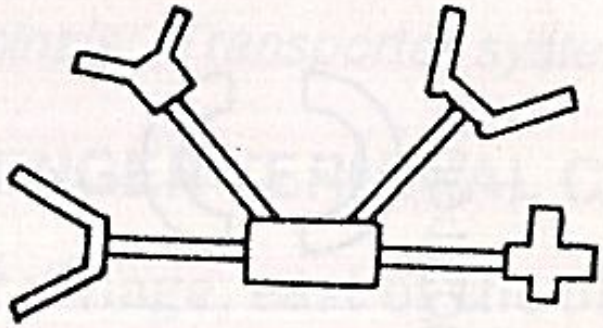
Transporter/ Satellite Concept

- Satellite System
  - Consists of central building for processing of passenger and baggage
  - Use remote concourse around which aircraft is parked
  - Remote concourse are connected to the terminal building above or below the ground (automated people mover system)





Paris/De Gaulle
(common terminal)

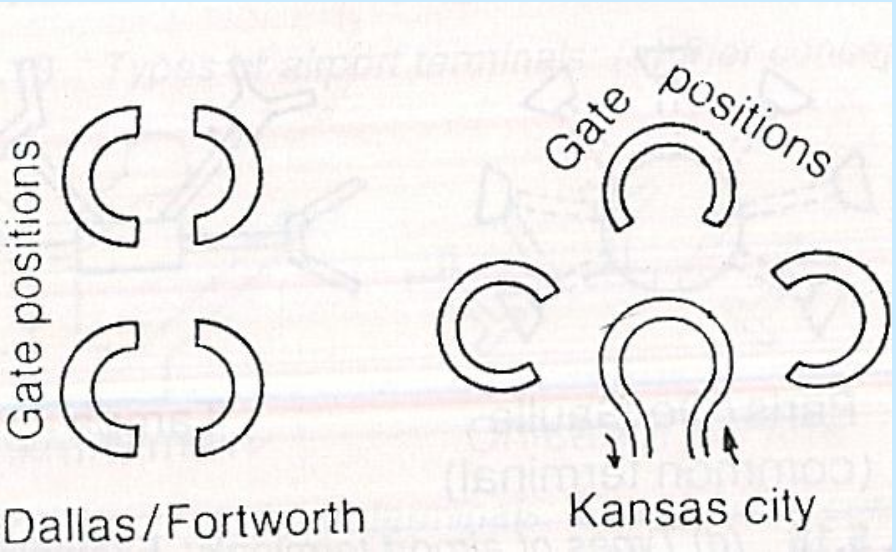


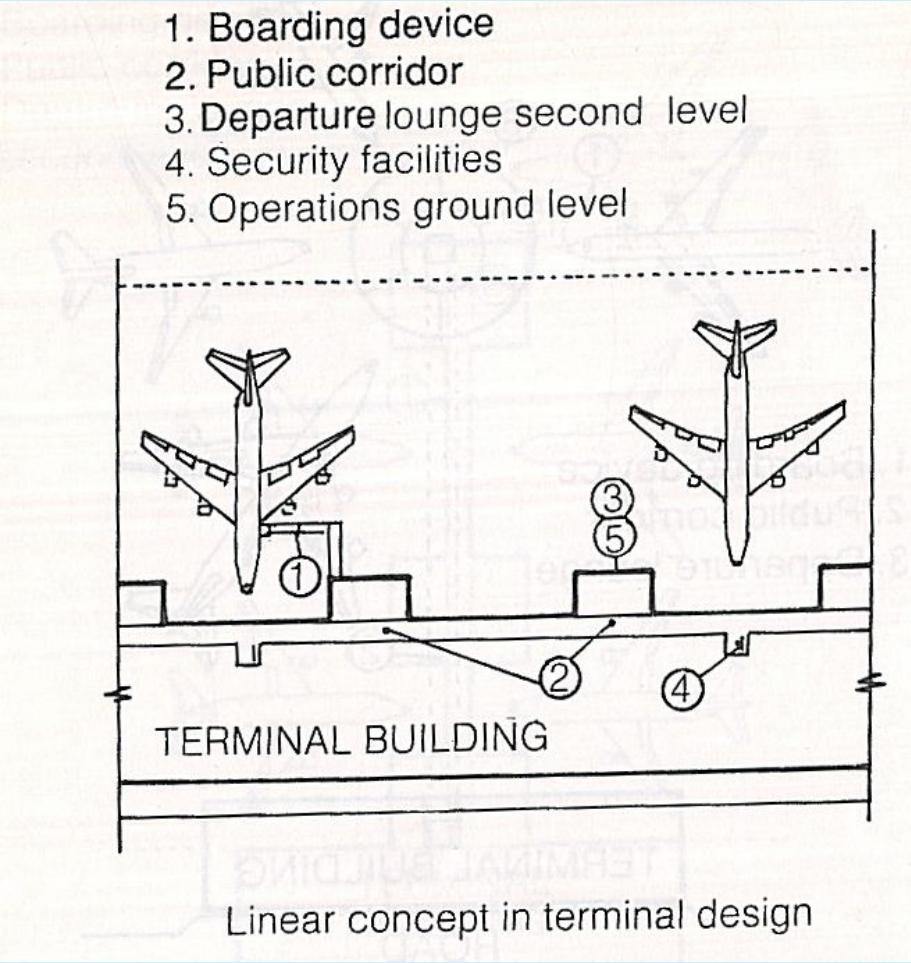
Tampa

Satellite Concept

Linear Concept

- Horizontally long building with expansion capability to either side by means of finger type concourse
- Aircraft parked at the face of the terminal.





Linear concept in terminal design

Advantages

- Minimum walking distances if check in facilities are decentralized
- Easier passenger orientation
- Simple construction of main terminal
- Adequate curb length

Disadvantages

- Decentralized require duplication of terminal facilities
- Longer walking distance for transfer of passengers
- High operation and maintenance cost if centralized passenger and baggage operation is employed
- In decentralized system more extensive flight information system is required

Unit Terminal Concept- Semi Centralized

- Modules are constructed in stages according to capacity demand
- Expansion carried out through construction of additional modules
- Departing passengers and their baggage are processed either at gate check-in or semi-centralized facility
- Baggage sorting devices are not usually required

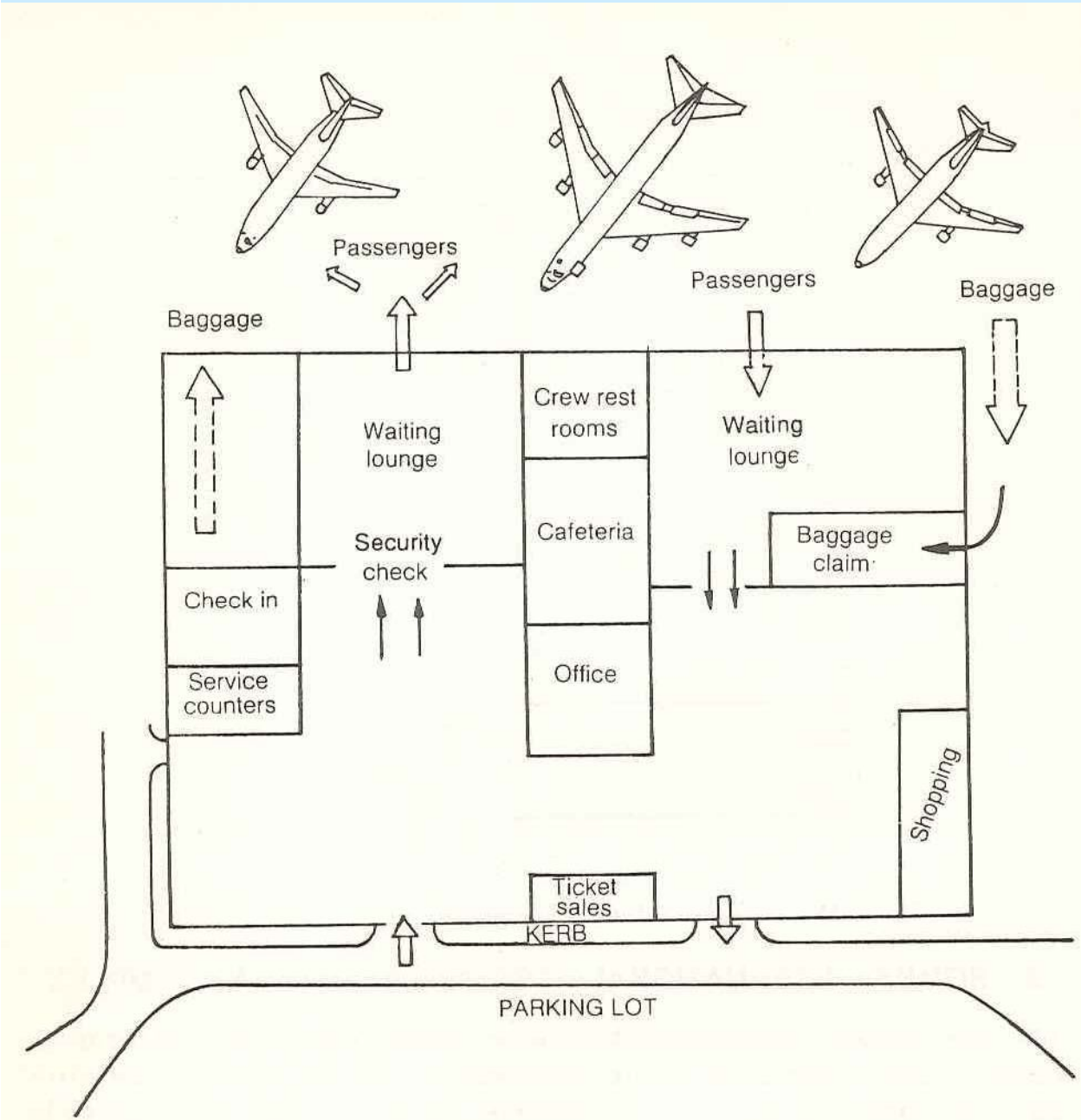


Fig. 5.18 *(h) Types of airport terminals: Simple general purpose layout–unit terminal concept*

Unit Terminal Concept Semi-centralized

Runway Geometrics

- Runway Length
- Runway Width
  - Runway Width Requirements
  - Runway Shoulders
  - Runway Turn pads
- Runway Slopes
  - Transverse Slopes
  - Longitudinal Slopes

Runway Width

- Depends upon geometric characteristics of aero plane
  - The distance between the outside edges of the main gear wheels
  - The distance between wings mounted engines
  - The wing span
- Operational elements
  - The approach speed of aeroplane
  - The prevailing metrological conditions

Runway Width (m) Requirement

Code Number	Code Letter					
	A	B	C	D	E	F
1	18	18	23	-	-	-
2	23	23	30	-	-	-
3	30	30	30	45	-	-
4	-	-	-	60	60	60

Runway Shoulders

- The area abutting the edge of the runway pavement is designated as runway shoulder
- Provide protection against Foreign Object Damage (FOD)
- Provide sufficient width so that wing mounted engines are protected against FOD.

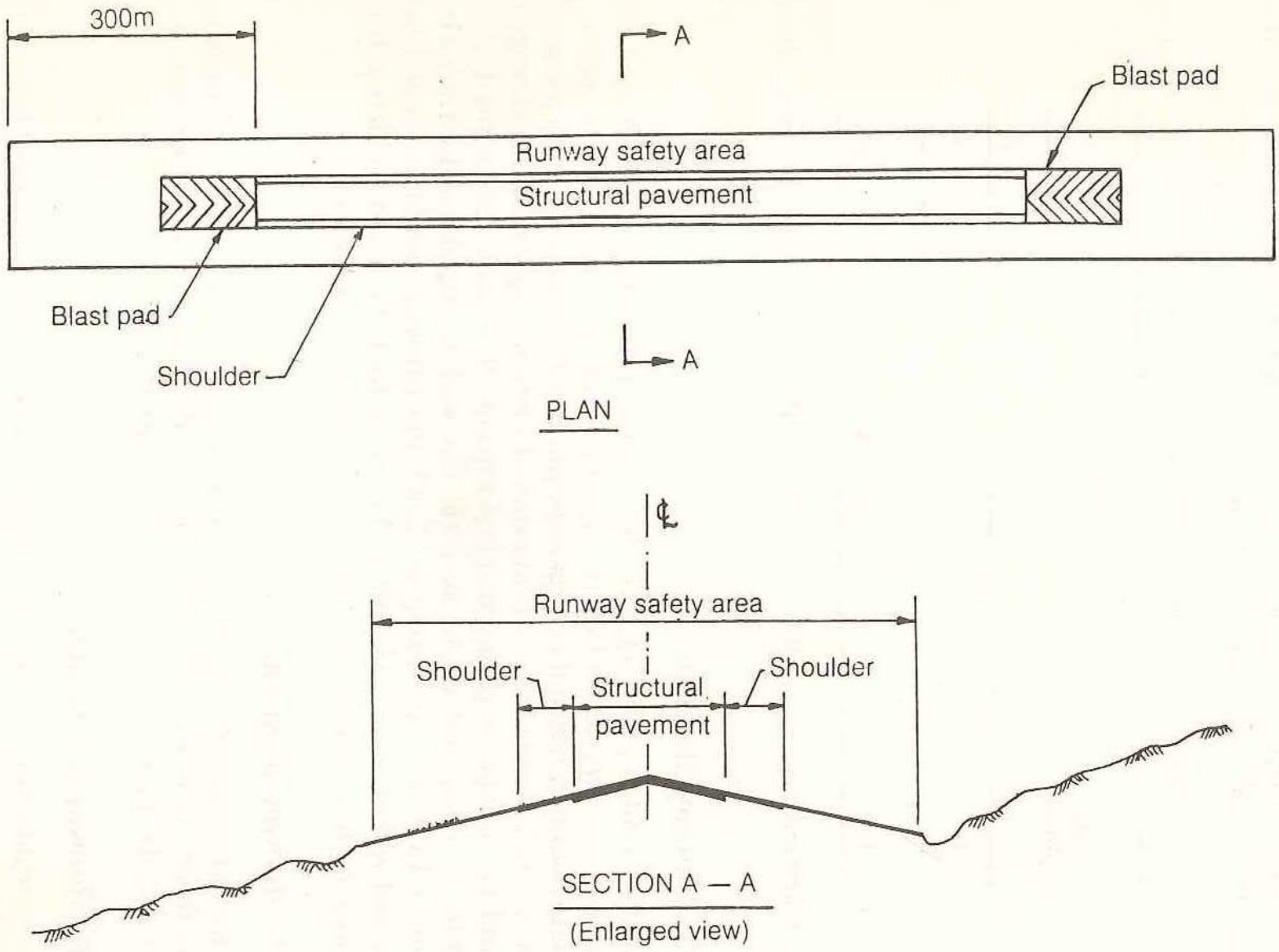


Fig. 5.7 *Runway safety areas, FAA*

Runway Shoulder (cont'd)

- For Code D and E overall width of the runway and shoulder should be at least 60 m.
- Bearing Strength
  - Turf over stabilized earth
  - Light asphalt pavement to support ground equipment and resist blast jet erosion.
- Cross slope
  - Runway = 1.5%
  - Shoulder = 2%

Runway Blast Pad

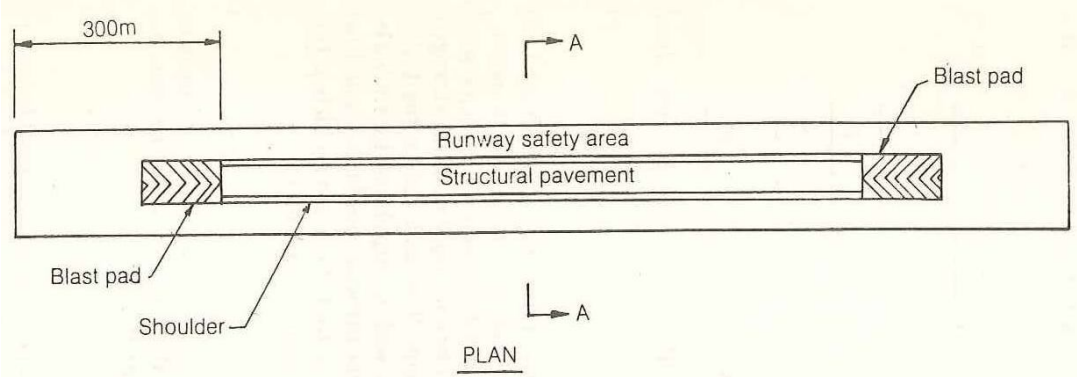
- An area abutting the ends of the runway serving the same function as a runway shoulder is called runway blast pad.
- As per requirements, its length is in the range of 30 to 120 m.

Turn Pads

- Turn pads are provided if the runway end is not served by the taxiway
- Minimum margin of safety between 1.5 m to 4.5 m should be provided between any wheel of the aeroplane landing gear and the edge of turn pad

Runway Slopes (Transverse)

- Provide drainage of water
- Cambered or one sided transverse slope provided
- Transverse slope between 1-2%
- Transverse grooving along with prescribed slopes may be advantageous



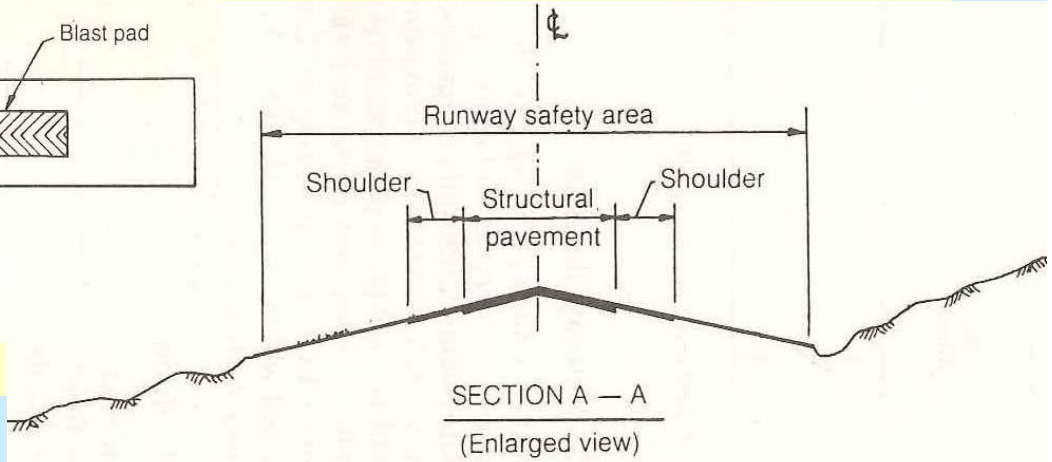


Fig. 5.7 *Runway safety areas, FAA*

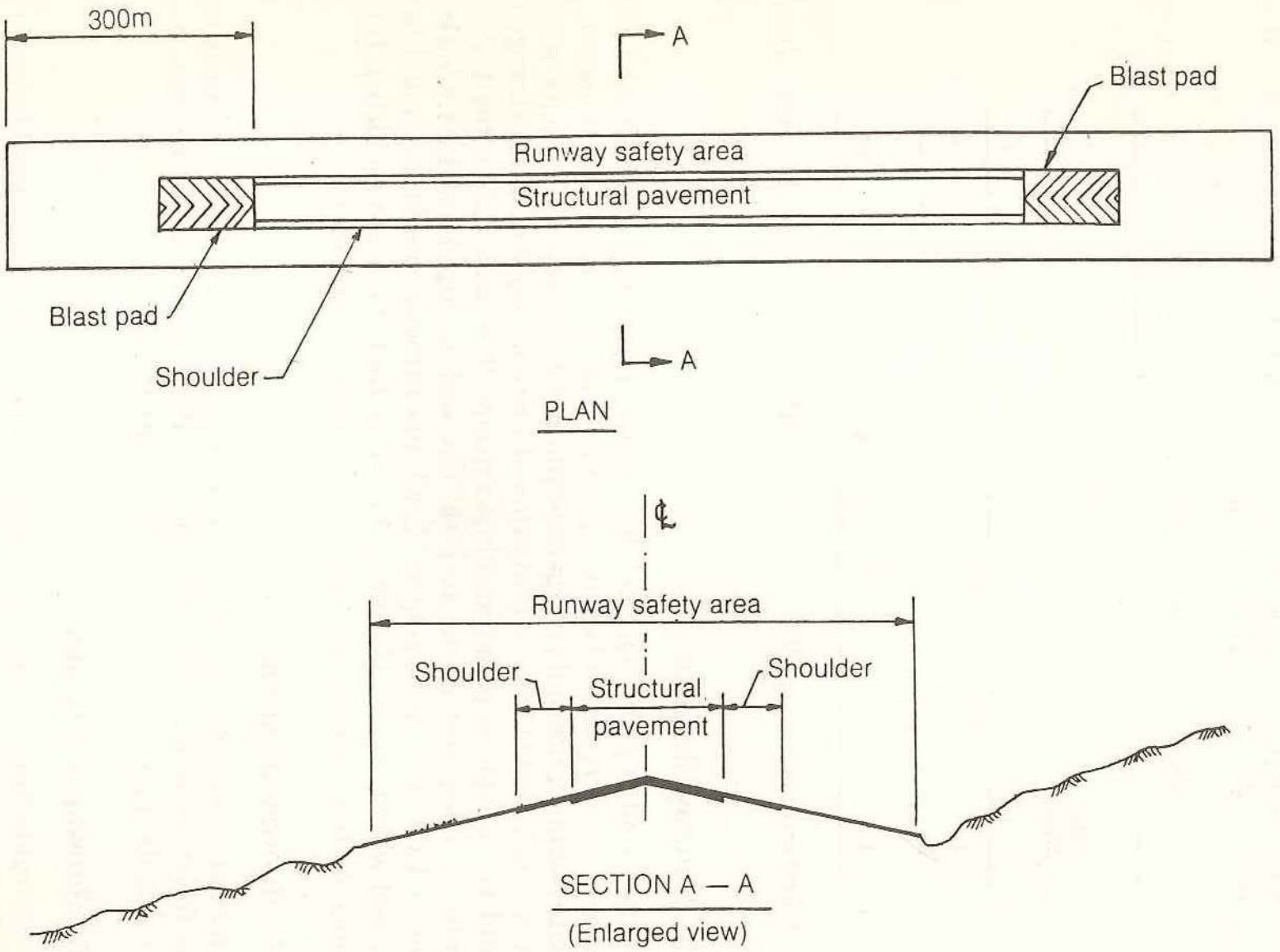
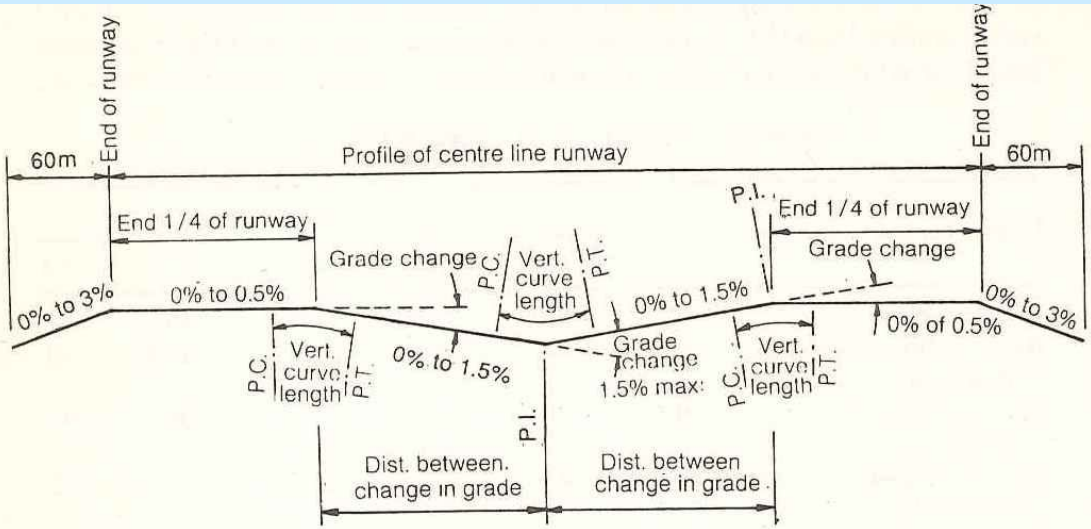


Fig. 5.7 *Runway safety areas, FAA*

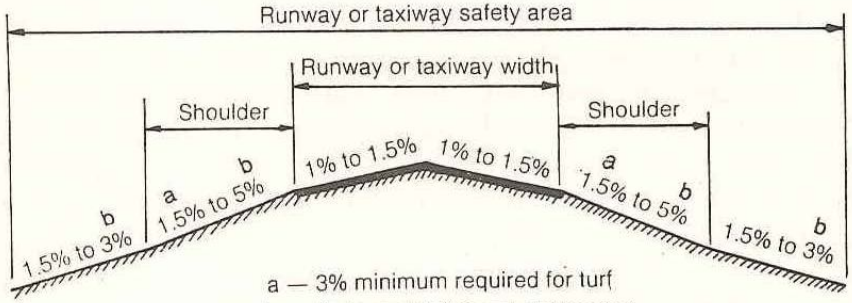
Runway Slope (Longitudinal)

- Few runways are level throughout their length and complete flat runway may require considerable earth work
- Slopes are usually limited to 1-2% but in special cases can be as high as 8% (one way runways) in mountain areas.
- Longitudinal slope changes are limited by
  - Runway profile (roughness)
  - To secure permanent and safe contact of the tires with the surface of the runway
  - Longer slope change limitation to ensure that pilot has adequate view of the runway
- Minimum radius of curvature at slope change vary from 7500-30000 m depending upon the code number of runway.



Minimum distance between change in grade = 300m x Sum of grade changes (in percent)
Minimum length of vertical curves = 300m x Grade change (in percent)

Fig. 5.8 *Longitudinal grade limitations for runways, FAA*



a — 3% minimum required for turf

b — A slope of 5% is recommended for a 3m width adjacent to the pavement edges to promote drainage

GENERAL NOTES

1. A 3.8 cm drop from paved to unpaved surfaces is recommended
2. Drainage ditches and swales may not be located within the safety area

Fig. 5.9 *Transverse grade limitations for runways, FAA*

Runway Surface

- ICAO recommends that the surface of a runway should be constructed without irregularities that may adversely affect the take-off and landing by causing excessive bouncing / pitching
- It should provide good friction even when wet.
- Sometimes, the surface of the pavement is grooved to improve friction resistance

Imaginary Surfaces

- Imaginary surfaces are established with relation to the airport and to each runway
- The size of each imaginary surface is based on the category of each runway according to the type of approach available or planned for the runway.
- Requirement specified by ICAO (Part 77)

Imaginary Surfaces

- Primary Surface
- Horizontal Surface
- Conical Surface
- Transitional Surface

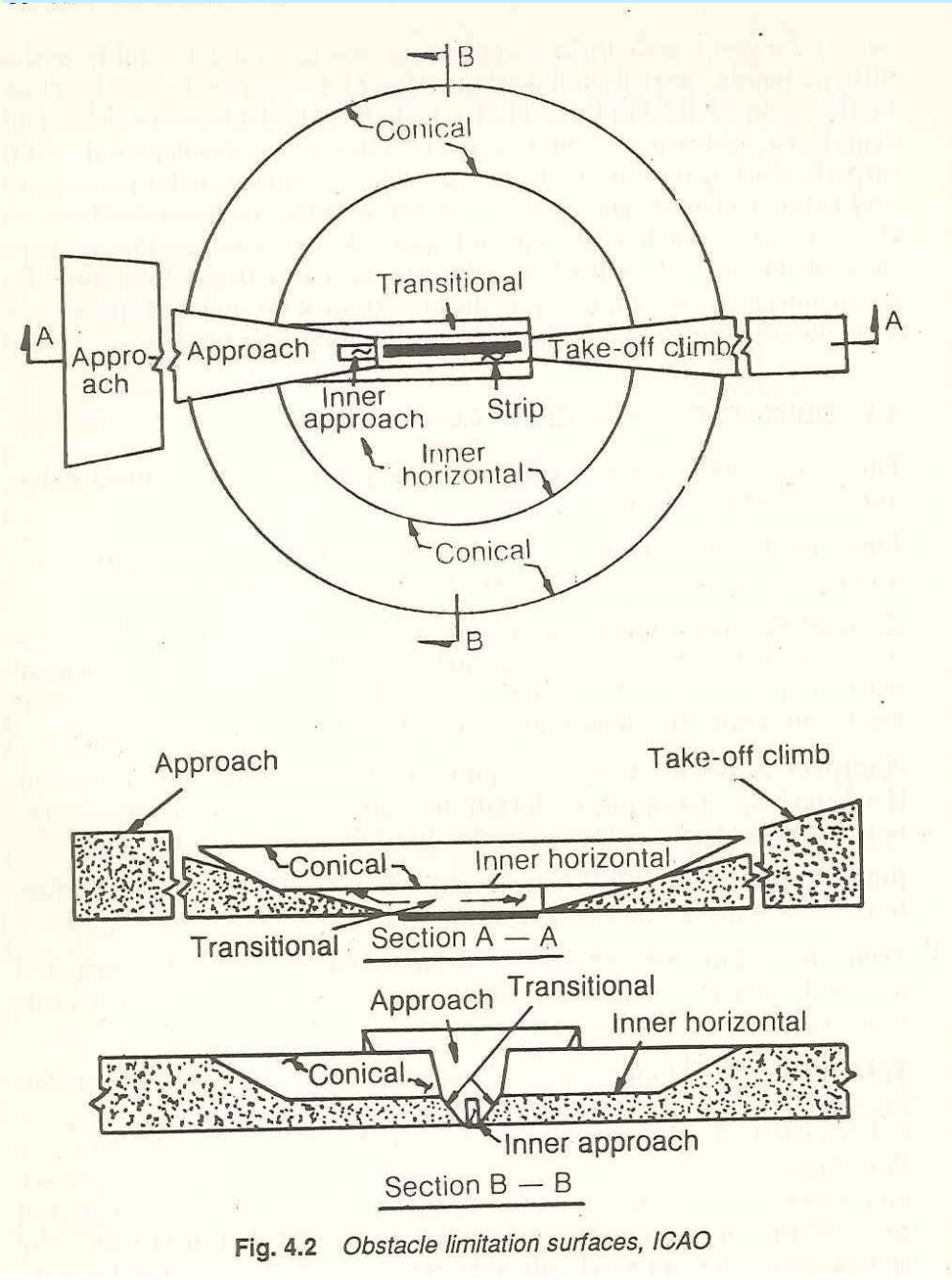


Fig. 4.2 *Obstacle limitation surfaces, ICAO*

Primary Surface

- A surface longitudinally centered on the runway. When runways has specially prepared hard surface, the primary surface extends 200 ft beyond either end of the runway but when the runway has no specially prepared surface the primary surface ends at the physical ends of the runway
- The elevation of any point on the primary surface is same as the elevation of nearest point on the runway centerline

Horizontal Surface

- A horizontal plane 150 feet above the established airport elevation, the parameter of which is constructed by swinging arcs of specified radii from the centre of each end of primary surface of each runway. Tangents then connect the adjacent arcs.

Conical Surface

- A surface which extend outward and upward from the outer limits of the horizontal surface for a horizontal distance of 4000 ft. The slope of conical surface is 20:1 (5%) measured in vertical plane. (20 horizontal to 1 vertical

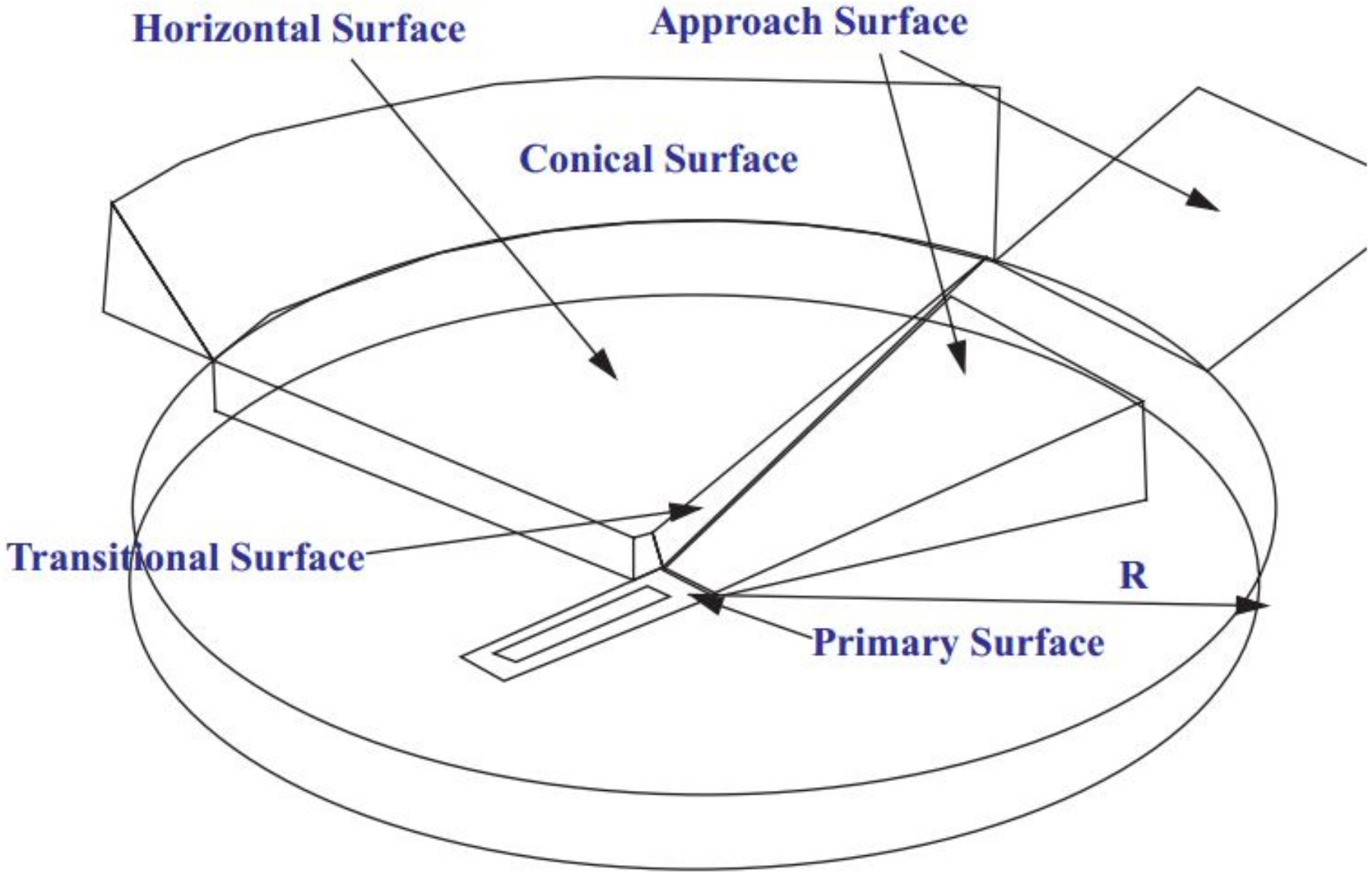
Transitional Surface

- A complex surface extending outward and upward at right angle to runway centerline and centerline extended from the side of primary surface and approach surface.
- Beyond the limits of the conical surface extends a distance of 5000 ft measured horizontally
- The slope is 7:1 and the surface extend beyond conical surface

Approach Surface

- The approach surface is a surface that is longitudinally centered on the extended runway centerline and extends outward and upward from each end of a runway at a designated slope on the type of available or planned runway approach.

Graphical Depiction



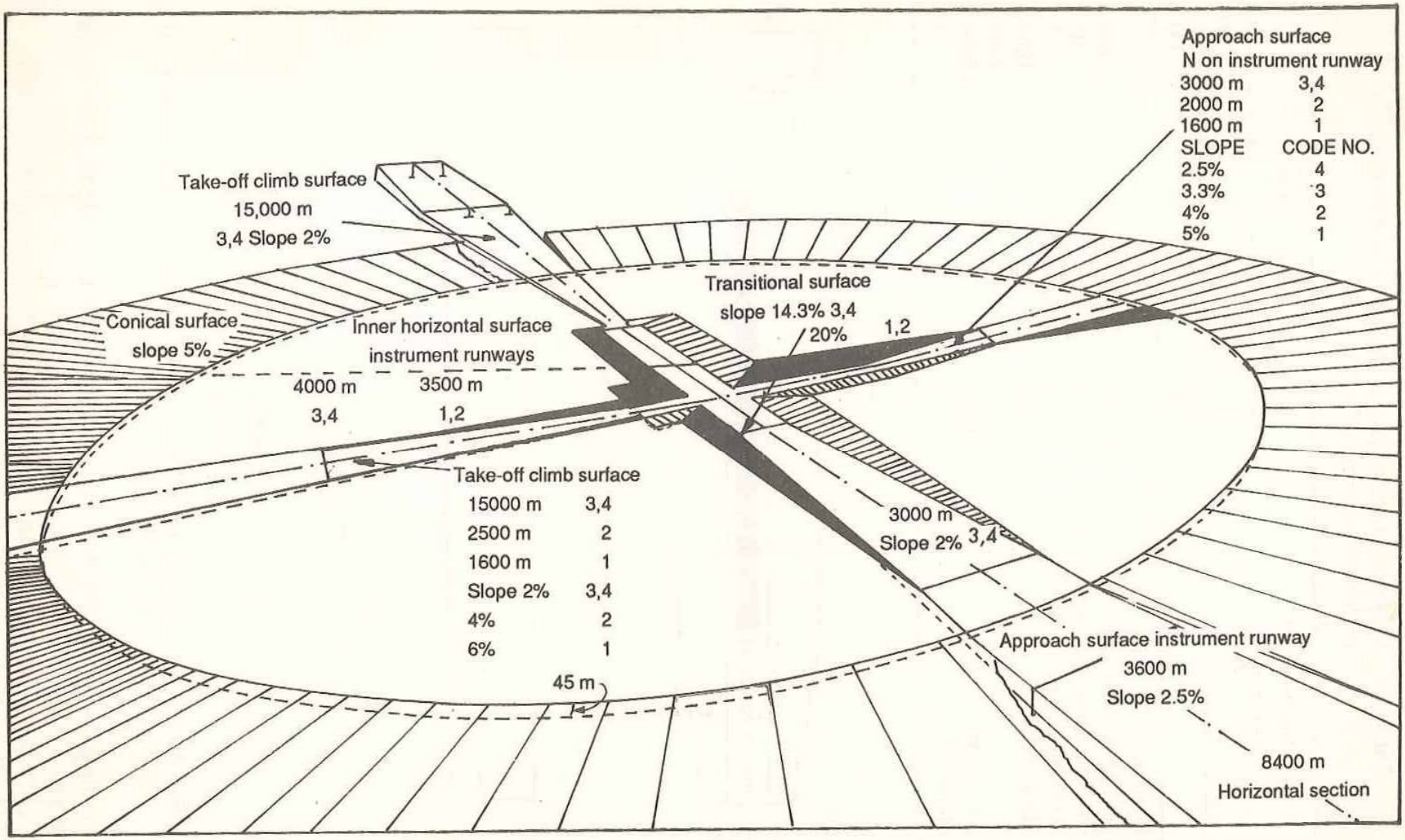


Fig. 4.4 *Obstacle limitation surfaces (3–D view), ICAO*

Runway Lighting and Marking (Need)

- Pilot need ground reference for navigating the aircraft for landing operation.
- The runway edges, the runway threshold and the centre-line of the runway are the most important marks which come to the aid of pilot.
- The landing operation in 3D coordinate system involves three translations and three rotations.
- Using all these six degree of freedom the pilot must touch down at a specific place on the runway while moving on desired reference path (glide path)

Six References used for Landing

- Three translations are
  - Lateral, vertical and forward movement
- Three rotations are
  - Pitch (with reference to horizontal axis)
  - Yaw (with reference to vertical axis)
  - Roll (with reference to axis parallel to runway)

Traffic Aids and Airport Marking

- The purpose of marking the various features of the airport is to enable the pilot to locate and identify the particular features indicated by marking.
- The traffic aids provided at the airport results in orderly flow of planes without any congestion and safe gaurds life and property.

Traffic Aids and Airport Marking

- Activities involved when aircraft moves from one airport to another are as follows
  - Taking off from the airport
  - Maintaining minimum altitude in the air
  - Navigation to the destination
  - Landing at the destination airport.
- Air traffic is controlled and regulated by
  - Network of air traffic control
  - Terminal area control
  - Airway communication
  - Enroute and landing aid

Air Traffic

- Network of air traffic control
  - The purpose of having air traffic control is to guide the aircraft during takeoff and landing operations.
  - To regulate aircraft traffic between apron and runway

Terminal Area Control

- This control is exercised from airport control tower which is in overall charge of aircraft movement in airport zone.
- The control tower is responsible for activities of the aircraft on the airport and in air within specified limits (airport zone).
- The control tower is located so that it commands a clear view of airfield the incoming aircraft are directed by means of a number of points located within 40 km.

Terminal Area Control (cont'd)

- Incase the runway is not free for receiving the aircraft it is directed by the control tower to keep moving at a specified height.
- Enroute control over aircraft is provided by a system Air Route Traffic Control Centers (ARTC)
- These centers are located at major airports in such a way that the entire country is covered under them.

Enroute Aids

- Airway Beacon
  - These are obsolete now.
- VOR (very high frequency omni-directional Range)
  - VOR signals are emitted along infinite number of courses. The pilots tunes the desired VOR frequency. The pilots get guidance regarding his course and find out whether he is heading in right or wrong direction.

Enroute Aids

- Low/ Medium Frequency Radio Range
- Distance Measuring Equipment (DME)
  - This instrument indicates to the pilot the distance travelled from the original station.
- Air to ground Communication
  - This is provided through flight service stations and ARTCS

Enroute Aids

- Tactical Air Navigation
  - This system has been developed by US Navy. It gives distances and azimuth in one unit and pilot can locate his position in air.
- Marker Beacons
  - As aircraft passes over the marker, there is visual indication in the cockpit.
- Direction Finder
  - The direction finder may be radio direction finder or automatic direction finder.

Landing Aids

- For smooth landing on the runway the aircraft is assisted by the following
  - Instrument Landing System
  - Precision Approach Radar
  - Airport Surveillance Radar
  - Airport Surface Detection Equipment

Instrument Landing System

- This system provide facility for landing even when pilot cannot distinctly see the ground references. When this facility is not available in the air field, the aircraft is diverted to another airport where visibility is better or ILS facility exist.
- ILS has three main components
  - Localiser Antenna
  - Glide Slope Antenna
  - Outer and middle marker

Precision Approach Radar (PAR)

- The PAR gives to the controller the picture of descending aircraft both in plan and elevation. The controller checks the alignment and guides slopes of the aircraft and direct the pilot.

Airport Surveillance Radar

- This is an instrument which provides the controller at the tower of all incoming and outgoing aircrafts.

Airport Surface Detection Equipment

- This is a short range radar specially suited for display of runways, taxiways and terminal areas and location aircrafts when visibility is poor.

Runways and Taxiway Marking

- White marking indicate runways.
- Taxiway marking are yellow
- Distance markers are used to indicate points 450 m from the ends of the runway
- Length symbols are used to indicate runway length
- A runway designation marking is located on the threshold. It is a two digit number and on parallel runways supplemented by letters L,R and C in given order.

Airport Lighting

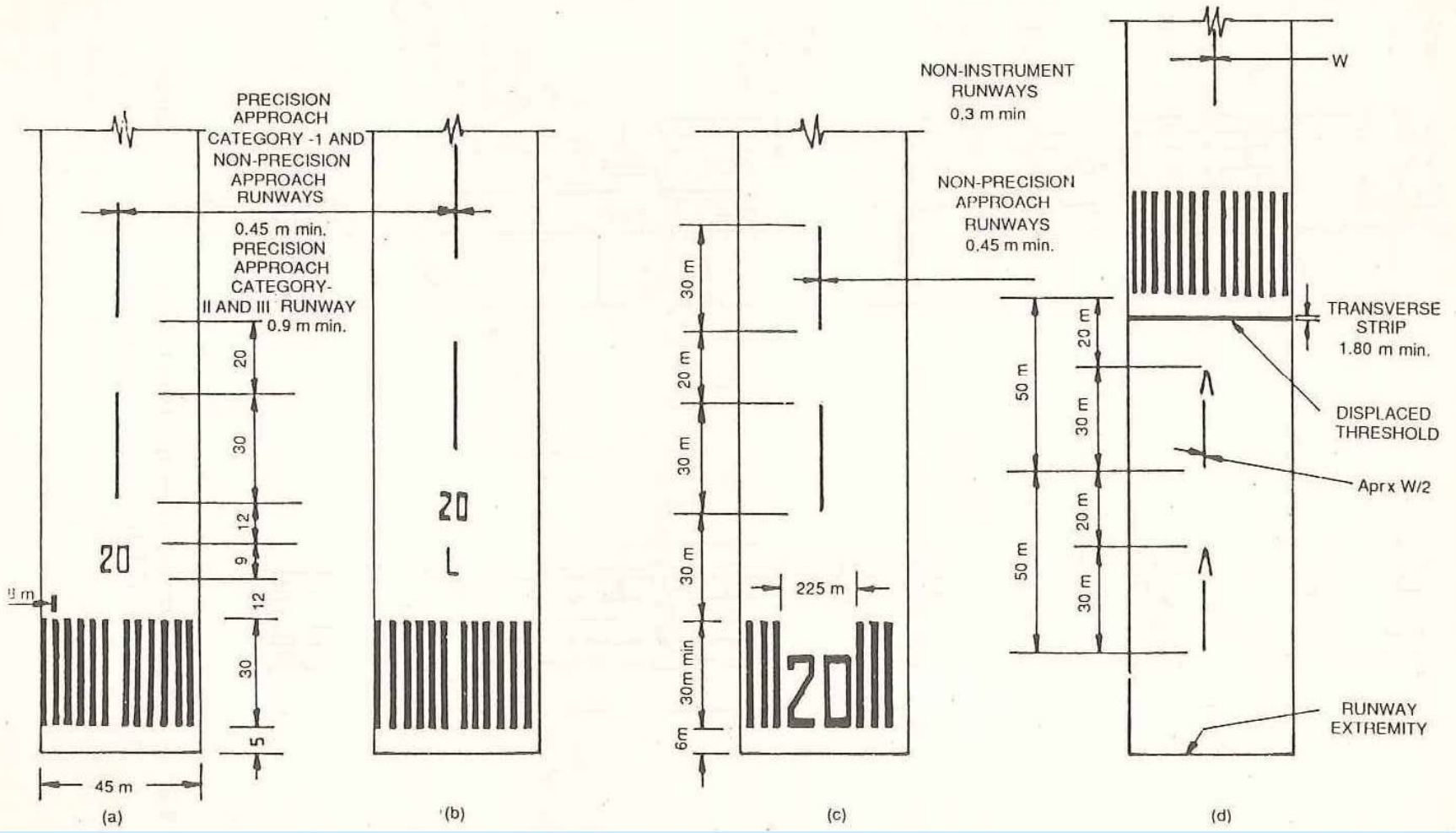
- During night or during day when visibility is restricted a system of signal light is used to convey information to pilots by standard colour scheme and configuration of lights.
  - Runway lighting
  - Threshold lighting
  - Taxiway lighting
  - Apron and hanger lighting
  - Approach lighting
  - Boundary Lighting
  - Code and rotating beacon

Landing Direction Indicator

Wind Direction Indicator

Runway Lighting

- Is planned in such a way that the pilots get the required guidance which enables him to judge his position with respect to lateral displacement, height and distance from air-field.
- Now a days narrow gauge patttern of lighting is adopted.
- The narrow gauge pattern form a channel of lights 18 m wide up to 1140 m from threshold. Beyond this closely spaced lights are placed along the centre line of the runway. The runway lights are white in colour.



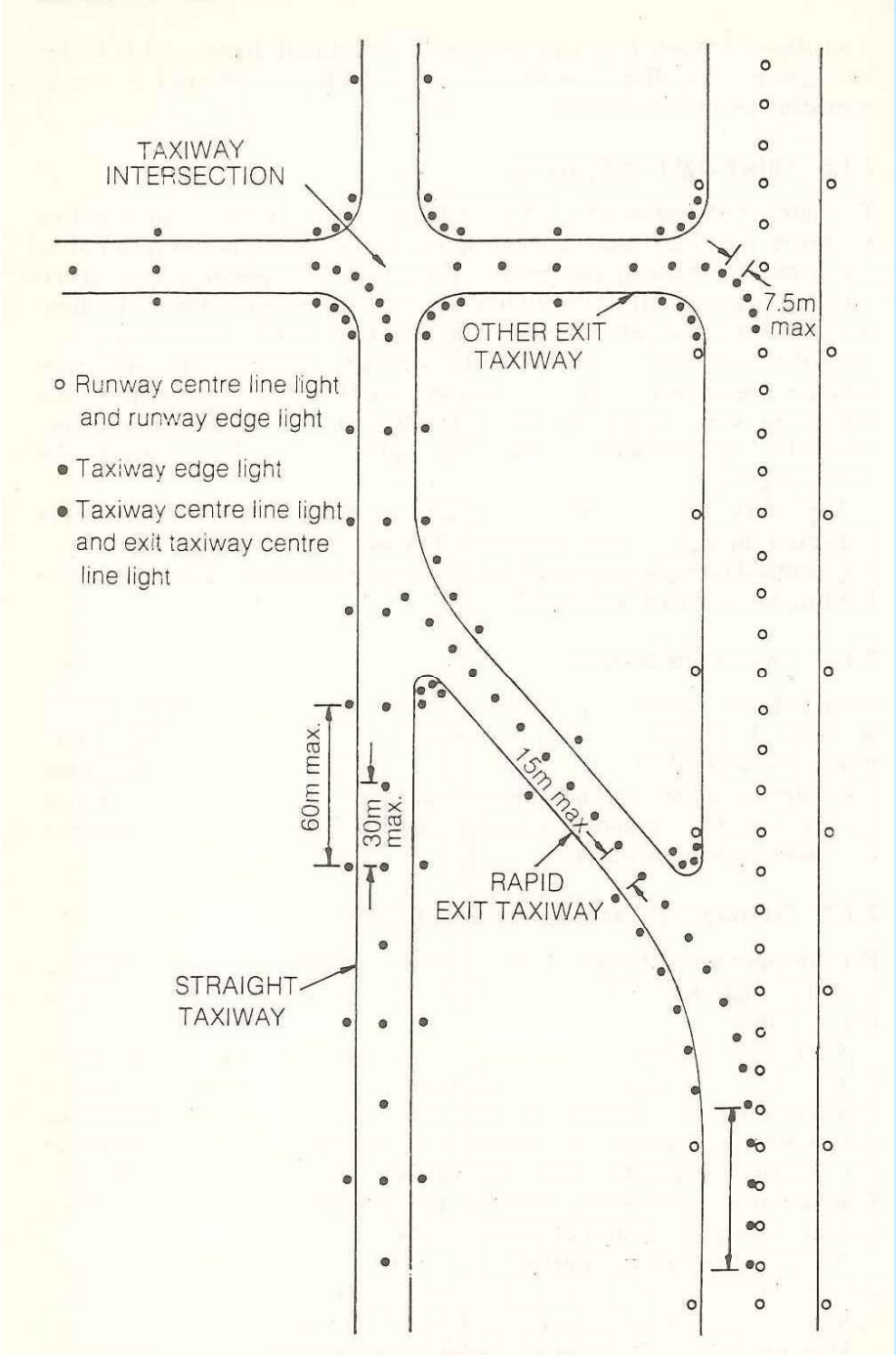
TYPICAL RUNWAY MARKING

Threshold Lighting

- The area near the runway threshold requires special consideration.
- The end of threshold lighting is indicated by terminating bars of red light placed 60 m from threshold.
- 30 m from threshold are red coloured wing bar lights which serve as distance indicator
- The threshold is lighted with a line of green lights over the entire width of runway.

Taxiway Lighting

- The taxiway is lighted in such a way that the pilot is able to differentiate between runway and taxiway.
- Pilot is able to locate the exit 350 to 450 m ahead of the point of turning.
- Apron and Hanger Lighting
  - Is so mounted that it does not cause any glare to pilots, passengers or crew.



Taxiway Lighting

Approach Lighting

- The pilots normally take landing decision when he is above 60 m above the runway.
- After the pilot sees the visual aid reaction time of about 3 sec is required before he reacts.
- Approach lights are usually mounted on pedestal of varying heights

Boundary Lighting

- The entire boundary of airfield is provided by boundary lights at 90 m centers. Usually these lights are provided 3 m inside the fence.
- Code Beacon
  - This light is provided sufficiently high so that the beam is clear off obstructions.
- Rotating Beacon
  - This beacon is usually mounted on top of terminal building or Hangers.

Airport Drainage

- Is one of the most important aspect of airport construction and maintenance. If the run-off is not quickly drained from runways/ taxiways/ apron it is very hazardous for airplane take-off as well as landing. Poor drainage adversely influences the pavement performance and life. Primary function of airport drainage is
  - quick removal of surface run-off
  - Sub-surface drainage
  - Diversion of water inflow from neighbourhood

Surface Drainage

- At the outset, it is necessary to select a design storm for which drainage is designed.
- FAA recommends a design storm which is probable once in five years.
- However, it is also necessary to check 10 to 15 years storm in order to assess the interruption to operations that will arise.

Sub-Surface Drainage

- The primary purpose of sub-surface drainage is to prevent the entry of water into sub-grade and the base course of the pavement.
- This is particularly necessary for clayey subgrade in view of their susceptibility to moisture ingress as well as frost action

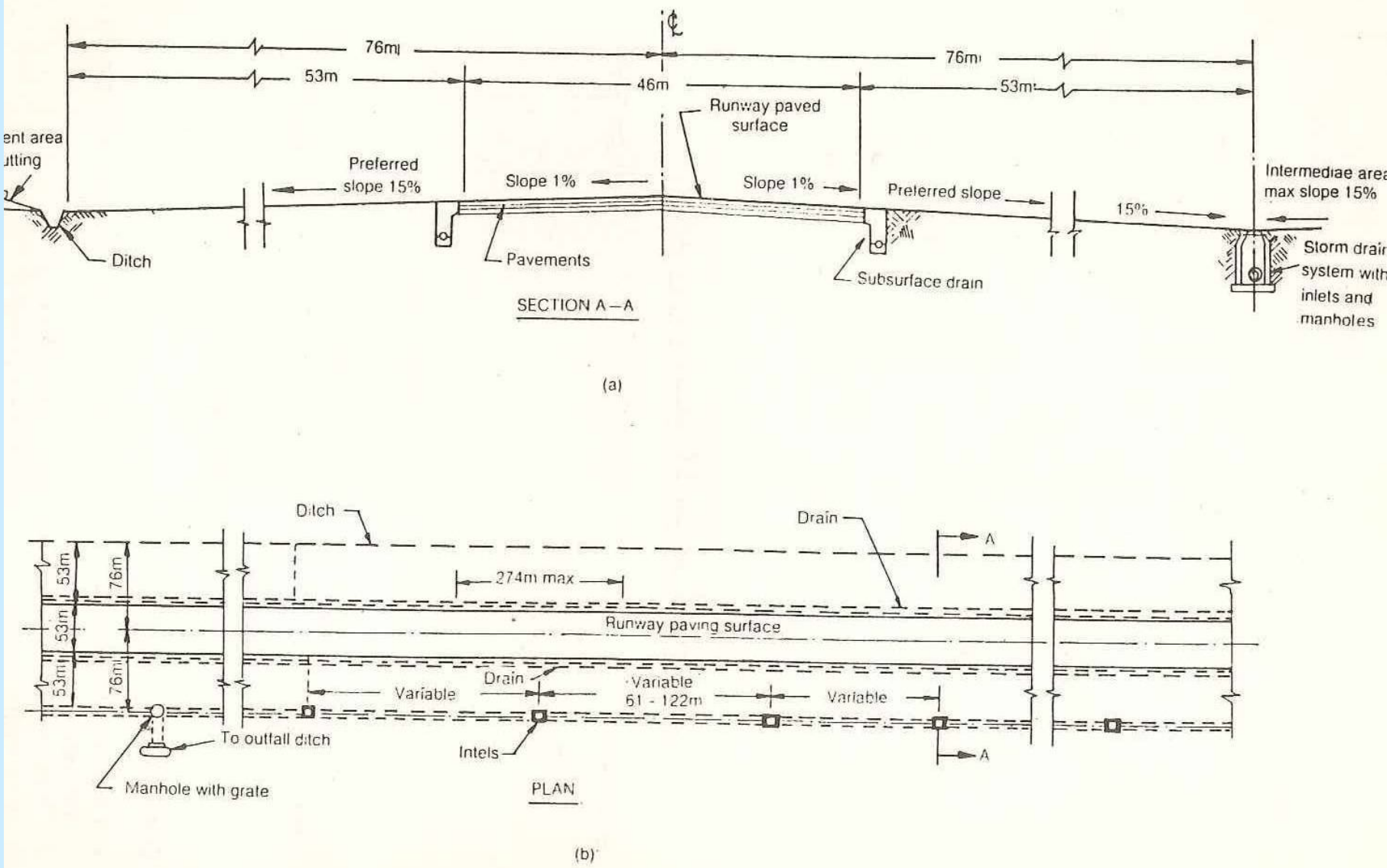


Fig. 7.9 *Typical runway drainage system—(a) Section A-A; (b) Plan view*

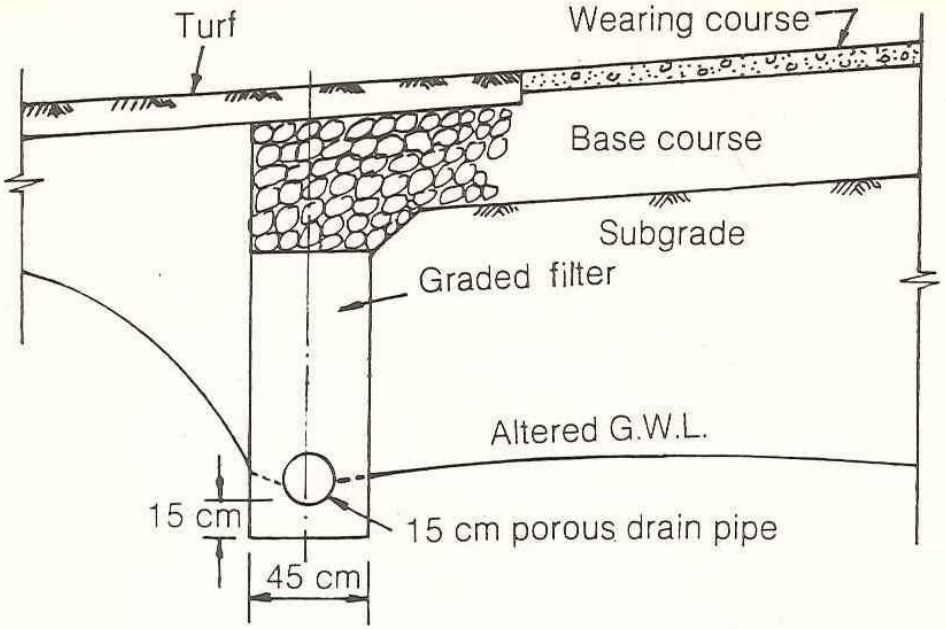


Fig. 7.9 *Typical runway drainage system—(c) Detailed cross-section of subgrade drain*

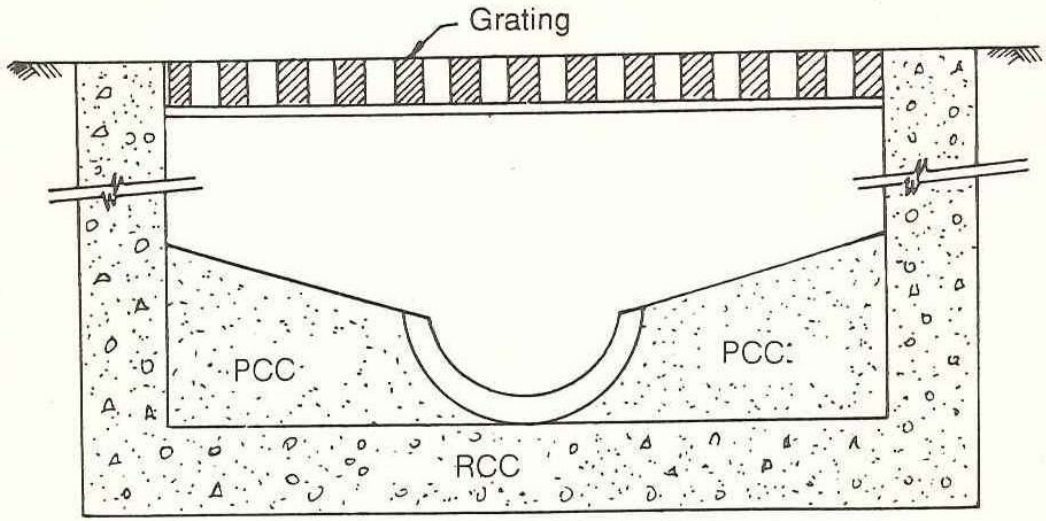


Fig. 7.9 *Typical runway drainage system—(d) Detailed cross-section of an inlet structure*