RUNWAY DESIGN

RUNWAY DESIGN

- Runway Orientation
  - Crosswind
  - Wind Coverage
  - Calm Period

- Wind Rose Diagram

- Runway Length

RUNWAY ORIENTATION

- Orientation of a runway depends on
  - Direction of wind
  - Area available for development

- Determination of a runway orientation is a critical task in the planning and design of an airport

RUNWAY ORIENTATION

- Runways are always oriented in the direction of prevailing wind.
- Reason behind it - to utilize to the maximum the force of wind at the time of take-off and landing of an aircraft
  - Lift and drag produced

RUNWAY ORIENTATION

- The direction of the runway controls the layout of the other airport facilities, such as

  - passenger terminals
  - taxiways/apron configurations
  - circulation roads
  - parking facilities

RUNWAY ORIENTATION

- Following points need to be considered while orienting the runways and taxiways:
  - Avoiding delay in the landing, taxiing and take-off operations and least interference in these operations
  - Providing the shortest taxi distance possible from the terminal area to the ends of the runway
  - Making provision for maximum taxiways so that the landing aircraft can leave the runway as quickly as possible to the terminal area
  - Providing adequate separation in the air traffic pattern

RUNWAY ORIENTATION

- Data required
  - Map of area and contours

    - To examine the flatness of area

    - Possible changes in the longitudinal profiles

  - Wind data - Direction

    - Duration

    - Intensity of wind

    - Required for the development of wind rose diagram

  - Fog characteristics of the area

RUNWAY ORIENTATION

- Wind data
  - Wind Direction
    - To examine whether the wind will attack aircraft from the head side or tail side or from sides
    - Also the direction of wind is not same throughout the year
      - Maximum wind direction needs to be ascertained

RUNWAY ORIENTATION

- Wind data
  - Wind Intensity

    - In terms of velocity in km/hr

  - Wind Duration
    - Time period for which the wind of certain intensity blows in a certain direction

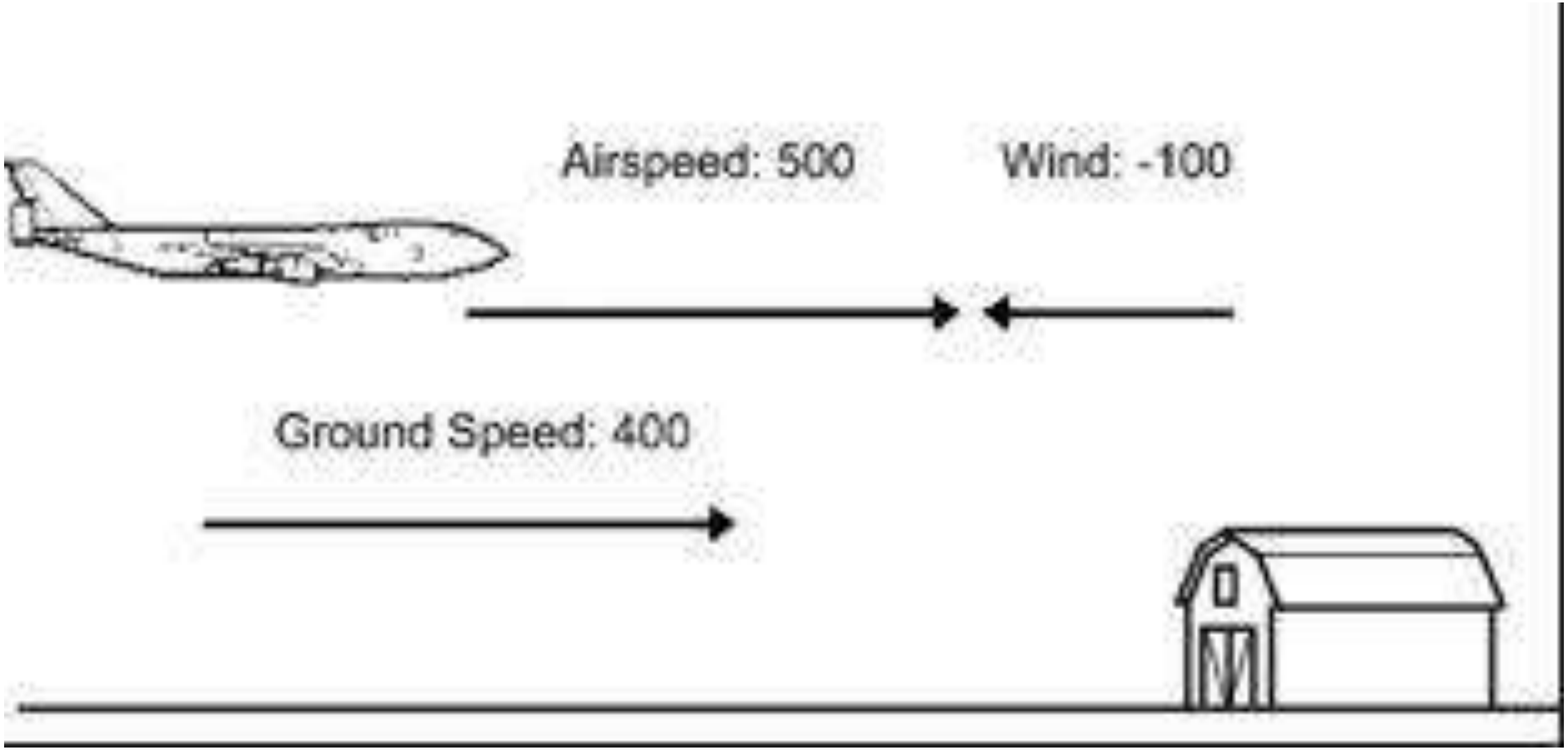
RUNWAY ORIENTATION

- Wind Direction
  - The direction of wind is variable and keeps on changing throughout the year. Its effect on aircraft movement is different and depends up on whether the wind acts as:
    - Head wind
    - Tail wind
    - Cross wind

RUNWAY ORIENTATION

- Wind Direction – Head Wind
  - The wind blowing from opposite direction of head or nose of the aircraft (or opposite to the movement of aircraft) while landing or taking-off is termed as Head wind
  - It provides braking effect during landing and greater lift on the wings of the aircraft during take off.
  - Thus the length of the runway gets reduced. This reduction may be around 10%

RUNWAY ORIENTATION



RUNWAY ORIENTATION

- Wind Direction – Tail Wind
  - This is defined as the wind blowing in the same direction as of landing or taking-off of the aircraft (or in the direction of movement of aircraft).
  - Provides push from the back thus increasing stop distance or lift-off distance.

RUNWAY ORIENTATION

- Wind Direction – Cross Wind
  - Transverse component of wind at 90º angle with the direction of aircraft movement is known as cross wind.
  - If the wind contains large component of cross wind then the aircraft may not maneuver safely on the runway
  - Excessive cross wind component might even veer off the aircraft away from runway, thus restricting the use of runway under such conditions.

RUNWAY ORIENTATION

RUNWAY ORIENTATION

- Wind Direction – Cross Wind
  - The maximum allowable cross wind depends up on
    - Size of aircraft
    - Wing configuration
    - Condition of pavement surface

  - For medium and light aircraft CW ≤ 25 kmph

RUNWAY ORIENTATION

- Wind Components – Cross Wind
  - The ICAO recommends maximum allowable cross wind component as

Reference Field Length	Maximum Crosswind Component
1500m or over	37 km/hr
1200m to 1499m	24 km/hr
<1200m	19 km/hr

RUNWAY ORIENTATION

- Wind Coverage
  - Wind coverage or usability factor of airport is the percentage of time in a year during which the cross wind component remains within the limit or runway system is not restricted because of excessive cross wind.
  - ICAO and FAA recommends minimum wind coverage of 95%.
  - When a single runway or a set of parallel runways cannot be oriented to provide the required wind coverage, one or more cross wind runways should be provided.

RUNWAY ORIENTATION

- Calm Period
  - This is the period for which the wind intensity remains below 6.4 km/hr
  - This is common to all directions and hence, can be added to wind coverage for that direction
  - Calm Period = 100 – Total wind coverage
  - OR = 100 - ∑Percentage of time wind is blowing in any direction

WIND ROSE

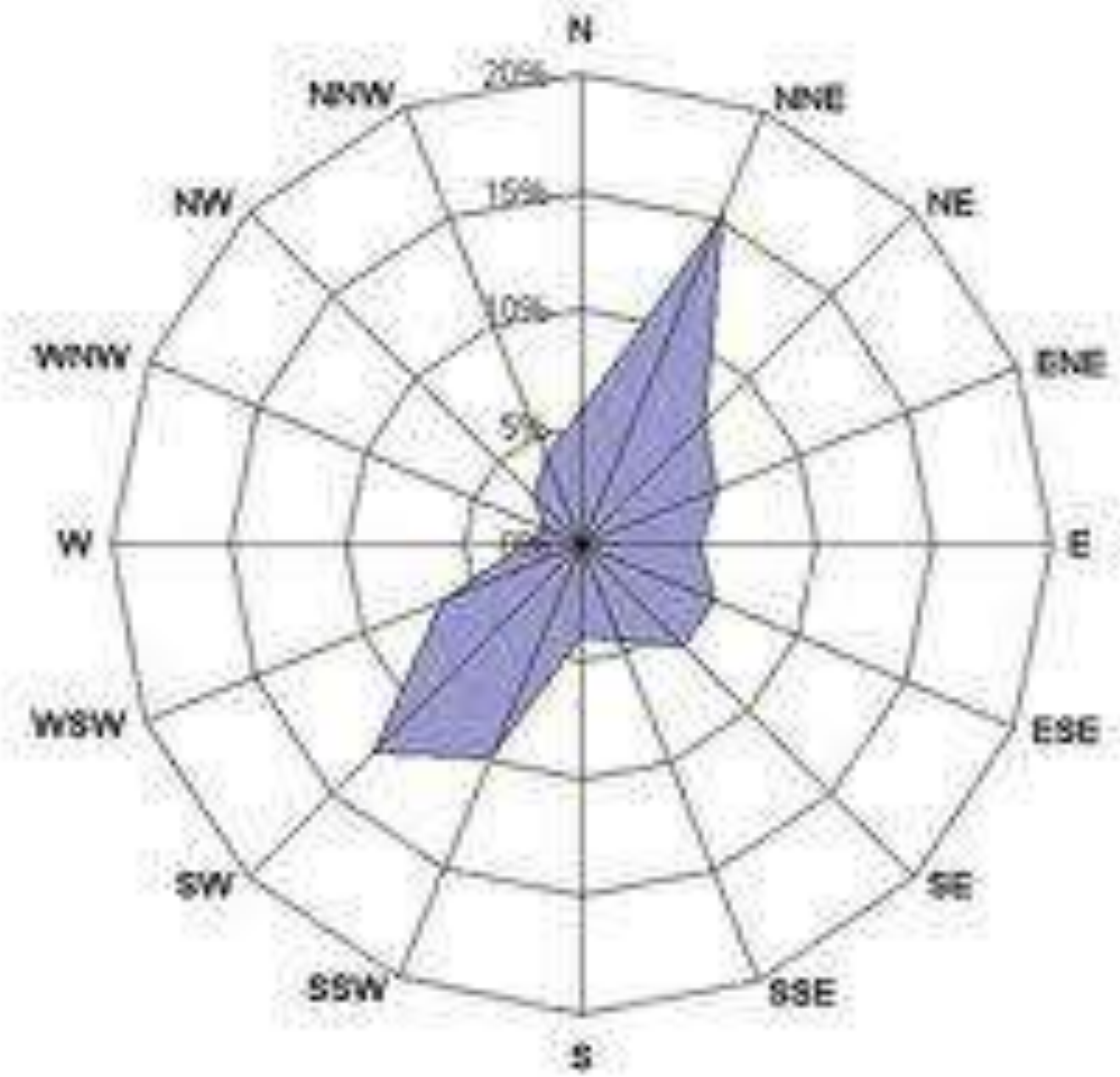
WIND ROSE

- Wind Rose
  - Application of WIND ROSE diagram for finding the orientation of the runway to achieve wind coverage.

  - The area is divided into 16 parts using an angle of 22.5º

  - Average wind data of 5 to 10 years is used for preparing wind rose diagrams.

WIND ROSE



WIND ROSE

- Wind Rose - Methods
  - Type – I : Showing direction and duration of wind
  - Type – II: Showing direction, duration and intensity of wind.

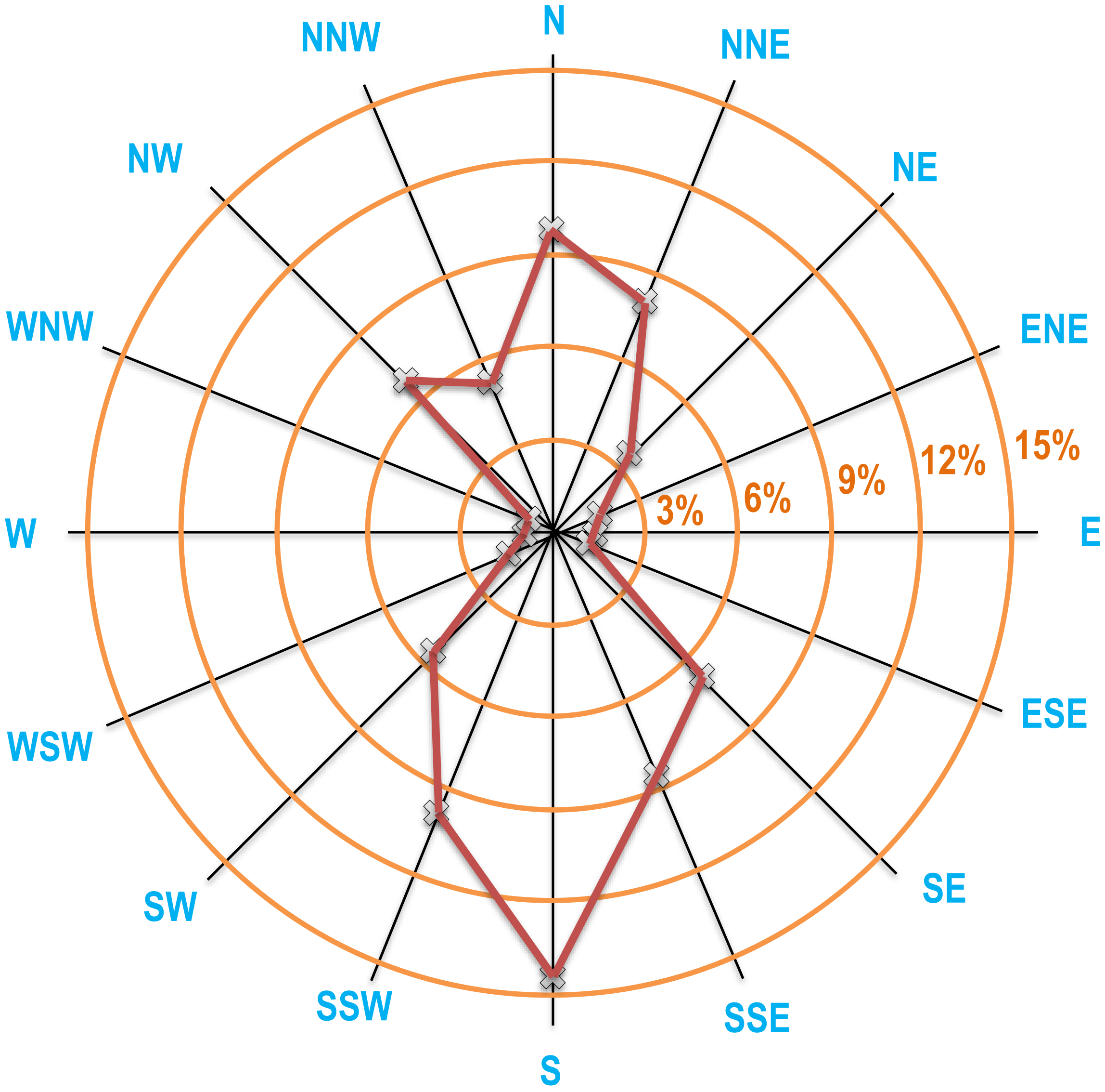
WIND ROSE

The following is the average wind data for 10 years. An airport is to be designed for a single runway. Determine the maximum wind coverage and the best direction of runway. The permissible cross wind component may be assumed as suitable for mixed category of aircrafts.

Wind Direction	Percentage of Time			Total in each direction percent
	6.4 – 25 km/hr	25 – 40 km/hr	40 – 60 km/hr	
N	7.4	2.7	0.2	10.3
NNE	5.7	2.1	0.3	8.1
NE	2.4	0.9	0.6	3.9
ENE	1.2	0.4	0.2	1.8
E	0.8	0.2	0.0	1.0
ESE	0.3	0.1	0.0	0.4
SE	4.3	2.8	0.0	7.1
SSE	5.5	3.2	0.0	8.7
S	9.7	4.6	0.0	14.3

Wind Direction	Percentage of Time			Total in each direction percent
	6.4 – 25 km/hr	25 – 40 km/hr	40 – 60 km/hr	
SSW	6.3	3.2	0.5	10.0
SW	3.6	1.8	0.3	5.7
WSW	1.0	0.5	0.1	1.6
W	0.4	0.1	0.0	0.5
WNW	0.2	0.1	0.0	0.3
NW	5.3	1.9	0.0	7.2
NNW	4.0	1.3	0.3	5.6
TOTAL				**86.5**

WIND ROSE – TYPE - I



WIND ROSE

- Wind Rose – Type – I
  - It is based on direction and duration of wind.
  - Minimum eight directions are taken but optimum is 16 directions.
  - Data includes total percentage of time in each direction.
  - Concentric circles are drawn to scale according to the percentage of time wind is blowing in a direction.
  - Total percentage in each direction is marked on the radial line drawn in that direction.

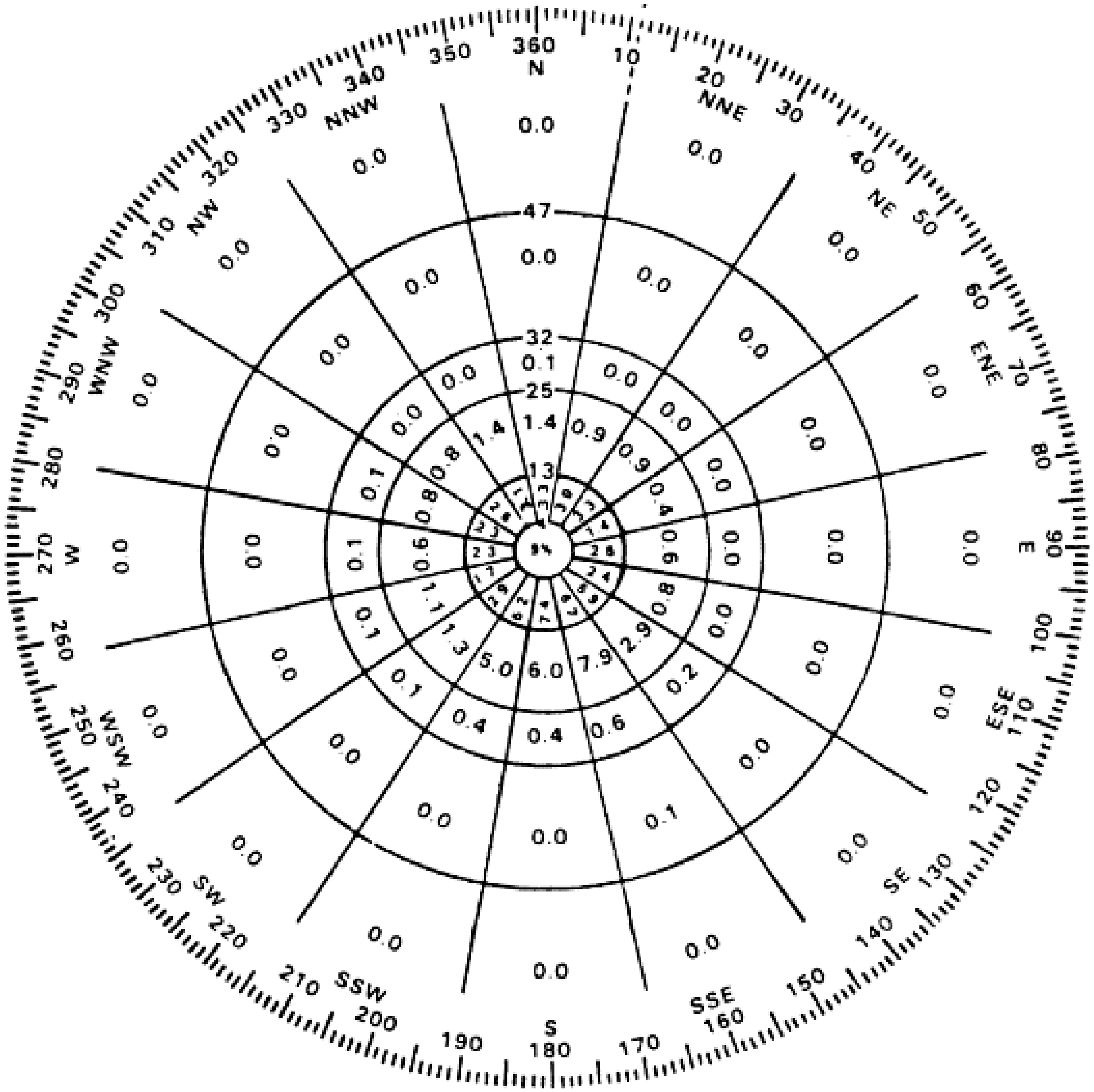
WIND ROSE

- Wind Rose – Type – I
  - These points on radial lines are joined together to form a duration map.
  - Best direction of runway is indicated along the direction of the longest line on the Wind Rose diagram.

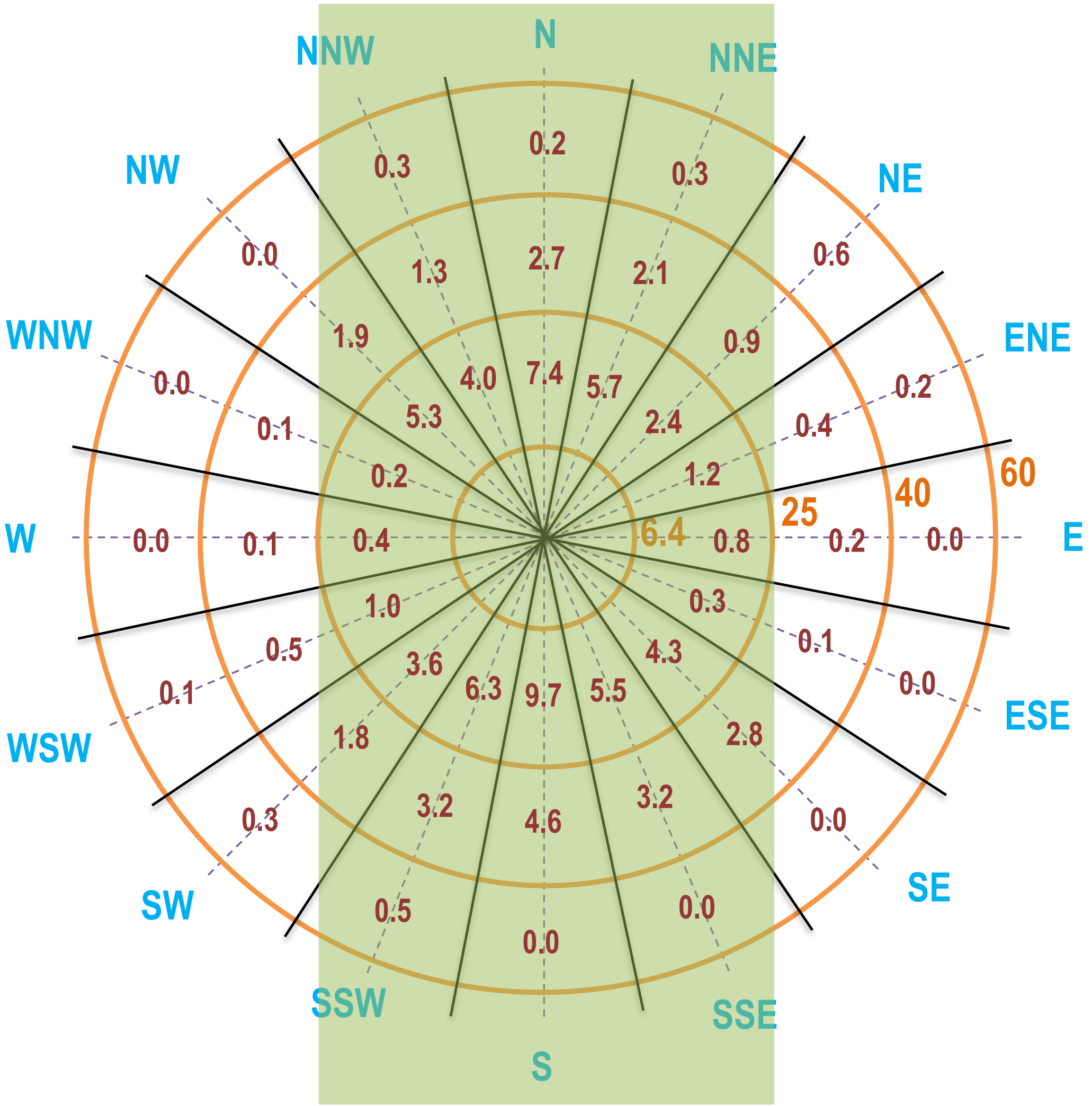
WIND ROSE

- Wind Rose – Type – II
  - It is based on direction, duration and intensity of wind.
  - Concentric circles are drawn to scale according to the wind velocity.
  - The influence of wind is assumed to spread at an angle of 22.5º in a direction.
  - Radial lines, from center, are drawn up to mid point of two directions thus dividing the space into 16 directions and 64 parts.
  - Categorized duration is marked in the related cell.

WIND ROSE – TYPE - II



WIND ROSE – TYPE - II



WIND ROSE

- Wind Rose – Type – II
  - Transparent rectangular template of length greater than the diameter of the diagram and width equal to twice of allowable cross wind component is made.

  - Wind rose diagram is fixed in position and the template is placed above it such that center of template coincides with center of diagram. The center line of template should pass through a direction.

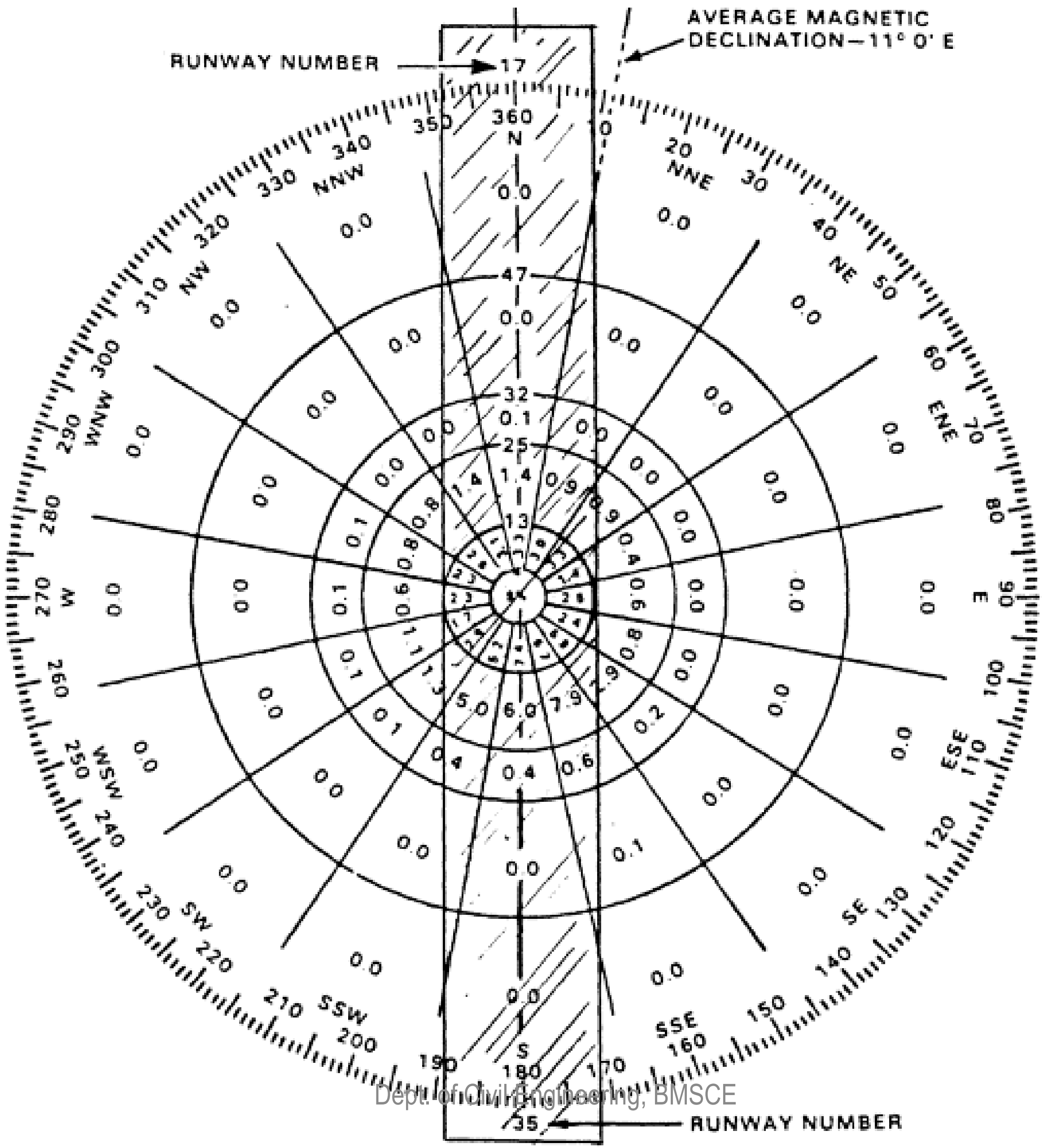
WIND ROSE

- Wind Rose – Type – II
    - The template is fixed in position and the sum of duration shown in cells superimposed by the template is calculated. This sum is shown as percentage and represents the total wind coverage for that direction.

WIND ROSE

- Wind Rose – Type – II
  - The template is then rotated and placed in next direction. The total wind coverage is calculated for that direction too.
  - Same procedure is adopted for all the directions.
  - The direction which gives the maximum wind coverage is the suitable direction for orientation of runway.
  - If a single runway is not sufficient to provide the necessary coverage then two or more runways should be planned to get the desired coverage.

WIND ROSE – TYPE - II



RUNWAY LENGTH

RUNWAY LENGTH

- Basic Runway Length

- Corrections to basic runway length

BASIC RUNWAY LENGTH

- Length calculated under the following conditions:-
  - No wind is blowing on runway
  - Aircraft is loaded with full loading capacity
  - Airport is at sea level
  - No wind is blowing on the way to destination
  - Runway is leveled., i.e zero effective gradient
  - Standard temperature of 15ºC at the airport
  - Standard temperature exists along the way

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Factors affecting the basic runway length –
  - Aircraft Characteristics
  - Safety requirements
  - Airport Environment

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Aircraft Characteristics
  - Power and propulsion system
  - Type of an aircraft
    - The “critical aircraft” is defined as being the aircraft type which the airport is intended to serve and which requires the greatest runway length.
    - To identify the “critical aircraft”, flight manual performance data of a variety of aircraft are examined.

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Aircraft Characteristics
  - Gross Take-off and landing weights of the aircraft
  - Aerodynamic and Mechanical characteristics

BASIC RUNWAY LENGTH-FACTORS AFFECTING

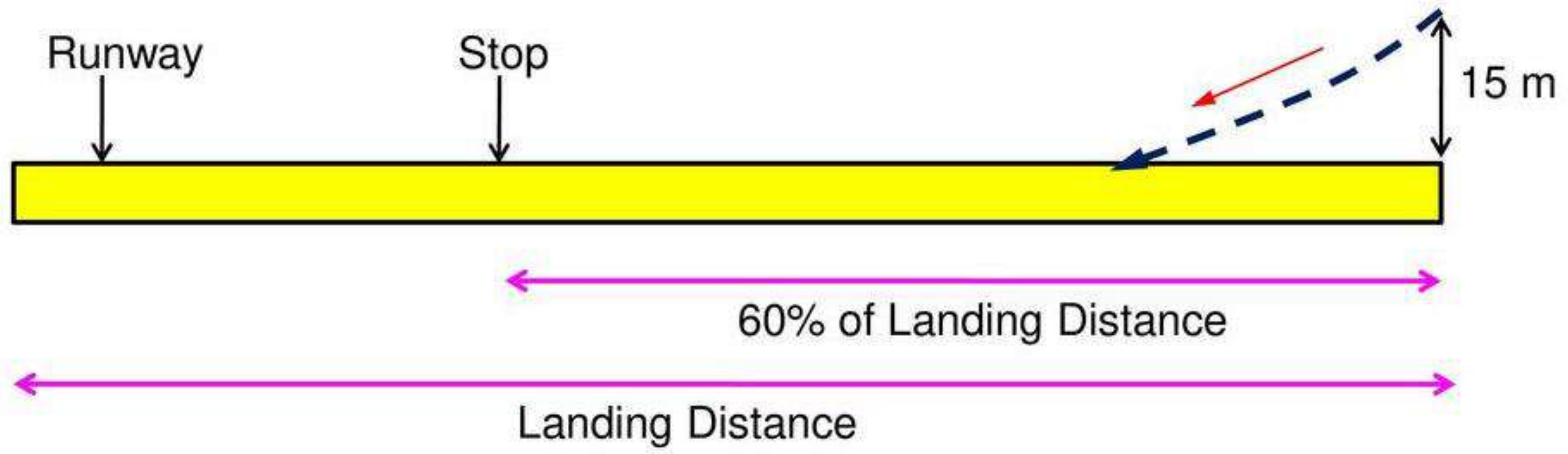
- Safety Requirements
  - Normal Landing
  - Normal Take-off
  - Stopping in Emergency

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Factors affecting –
  - Normal Landing
    - The aircraft should come to a stop within 60 percent of landing distance assuming that the pilot makes an approach at the proper speed and crosses the threshold of the runway at a height of 15m.
    - The runway of full strength is to be provided for the entire landing distance.

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- **Normal Landing**



BASIC RUNWAY LENGTH-FACTORS AFFECTING

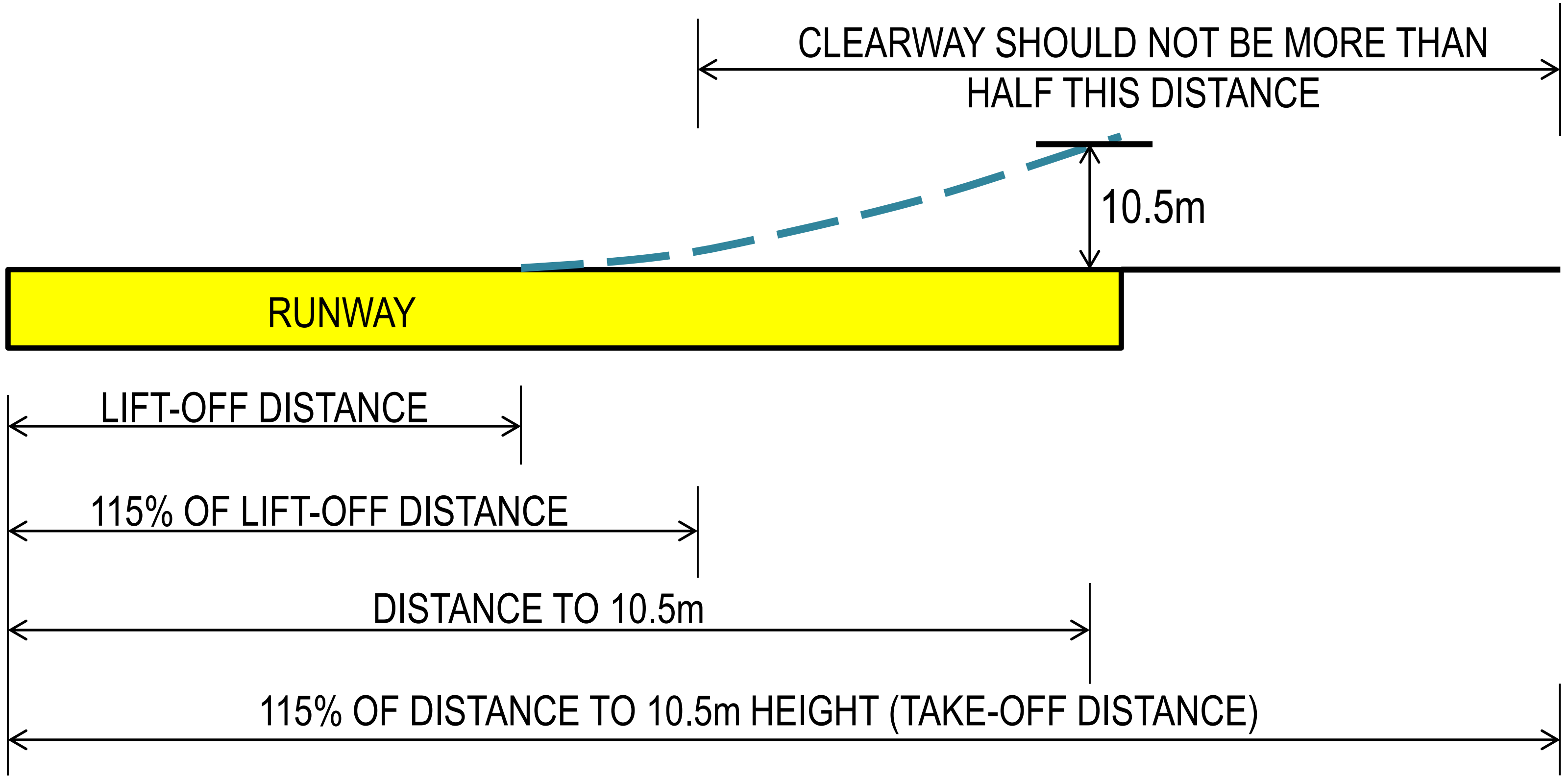
- Normal Landing: Calculations
  - Field Length(FL) = Landing distance (LD)
  - LD = Stopping distance (SD)/0.60
  - Length of full strength runway (FS) = LD

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Normal Take-off
  - The take-off distance must be, for a specific weight of aircraft, 115 percent of the actual distance the aircraft uses to reach a height of 10.5m.
  - The distance to reach a height of 10.5m should be equal to 115 percent of the lift-off distance.
  - It requires a clearway at the end of the runway in the direction of take-off. This should not be less than 150m wide. The upward slope of clearway from the end of the runway shall not exceed 1.25 percent.

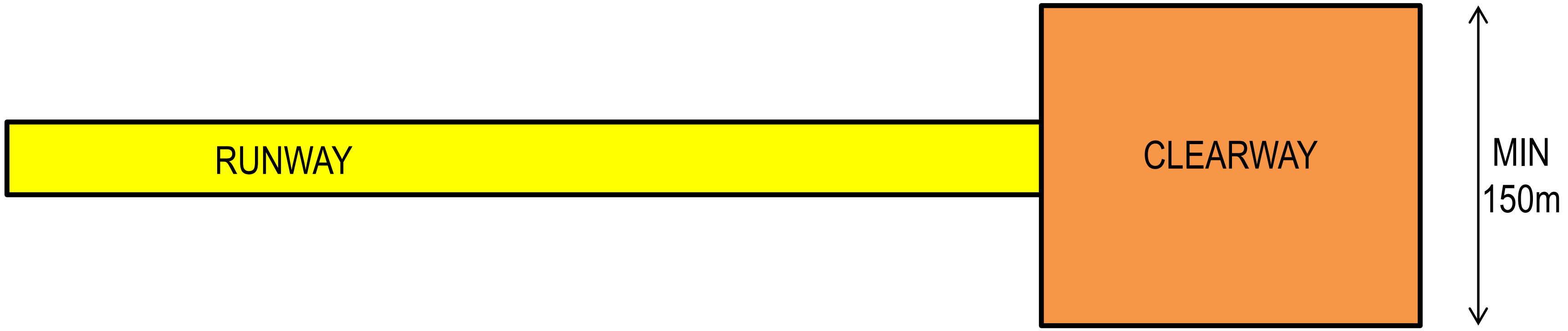
BASIC RUNWAY LENGTH-FACTORS AFFECTING

- **Normal Take-off**



BASIC RUNWAY LENGTH-FACTORS AFFECTING

- **Normal Take-off**



BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Normal Take-off: Calculations
  - Field Length (FL) = Full strength runway(FS) + Clearway (CW)
  - Take-off distance (TOD) = $1.15D_{10.5m}$
  - Clearway (CW) = 0.5[TOD – 1.15(Lift-off distance, LOD)]
  - Take-off Run (TOR) = TOD – CW
  - Length of full strength runway (FS) = Take-off run (TOR)

BASIC RUNWAY LENGTH-FACTORS AFFECTING

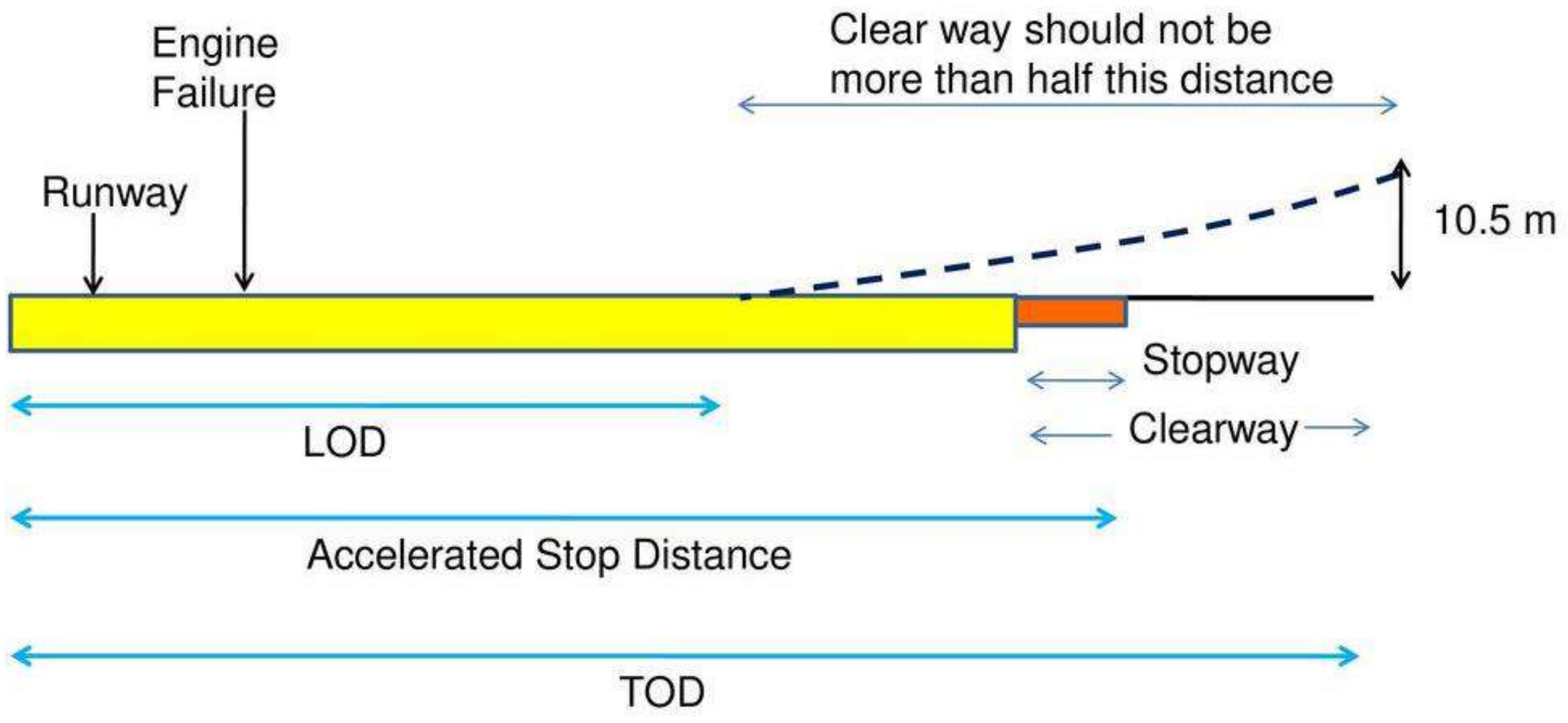
- Stopping in Emergency
  - For the engine failure case, the take-off distance is the actual distance required to reach a height of 10.5m with no percentage applied.
  - It also incidentally recognizes the infrequency of occurrence of the engine failure.
  - The aircraft accelerates to a speed V_1, before finding that the engine has failed and then it starts decelerating to stop at the end. Therefore, it requires a stopway along with a clearway.

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Stopping in Emergency
  - It is required to provide a clearway or a stopway of both in this case.
  - Stopway is defined as a rectangular paved area at the end of runway in the direction of take-off.
  - It is a paved area in which an aircraft can be stopped after an interrupted take-off due to engine failure.
  - Its width is at least equal to the width of runway and the thickness of pavement less than that of the runway, but yet sufficient to take the load of aircraft without failure.

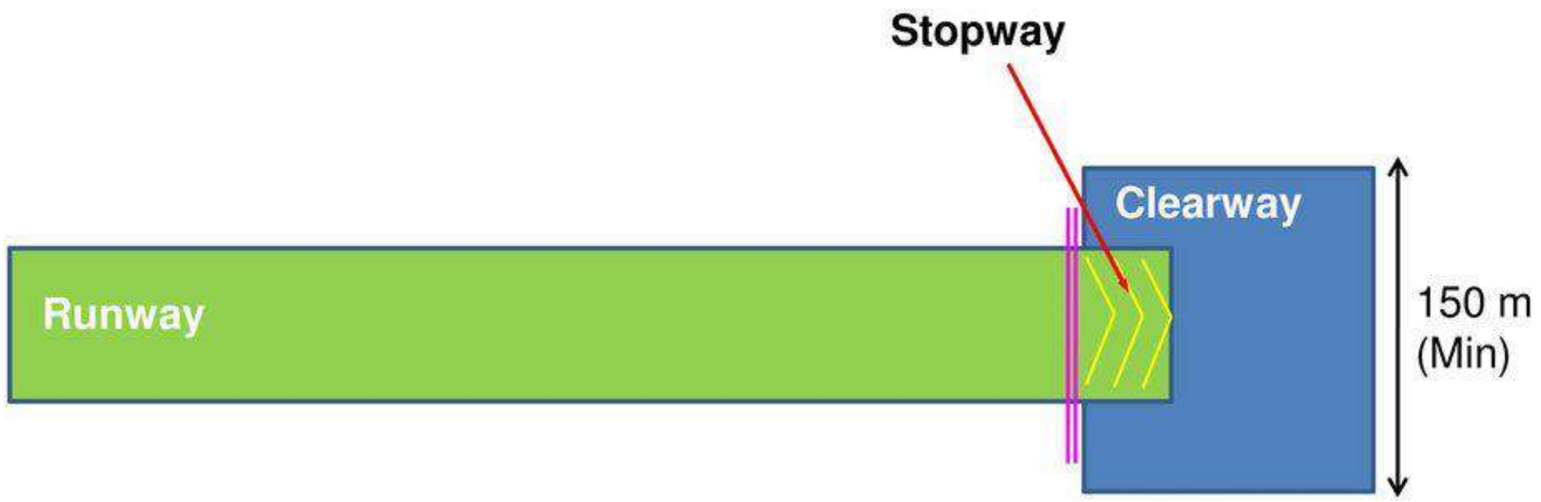
BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Stopping in Emergency



BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Stopping in Emergency



BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Stopping in Emergency - Calculations
  - Engine failure, Take-off proceeded case
    - Field length (FL) = Full strength runway(FS)+Clearway(CW)
    - Take-off distance (TOD) = $D_{10.5m}$
    - Clearway (CW) = 0.5[TOD-LOD]
    - Take-off Run (TOR) = TOD + CW
    - Length of full strength runway (FS) = Take-off run (TOR)

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Stopping in Emergency - Calculations
  - Engine Failure, take-off aborted case
    - Field length(FL) = Full strength runway(FS) + Stopway(SW)
    - FL = Accelerate stop distance (DAS)

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Required runway length
  - In case of Jet engine
    - All the three conditions are considered
  - In case of Piston engine
    - Only first and third cases are considered
  - ***The case giving the longest runway length is finally recommended***

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Required runway length
  - Field distance = max {TOD_2 , TOD_3, DAS, LD}
  - Full strength runway = max {TOR_2, TOR_3, LD}
  - Stopway = DAS – max {TOR_2, TOR_3, LD}
  - Clearway = min{(FL – DAS), CL_2, CL_3}
  - $Stopway_{min} = 0$
  - $Clearway_{min} = 0$
  - $Clearway_{max} = 300m$

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Airport Environment
  - Atmosphere
    - Temperature
    - Surface Wind
  - Location and Condition of Runway
    - Altitude
    - Runway Gradient

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Atmosphere
  - Standard Atmosphere
    - Temperature at MSL 15ºC
    - Pressure at MSL 760mm of Mercury(Hg)
    - Air density 1.225 kg/cu.m

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Atmosphere
  - Temperature
    - Temperature at Mean Sea Level
    - Airport Reference Temperature
    - Standard Temperature at an elevation
    - Monthly mean of average daily temperature for the hottest month of the year
    - Monthly mean of the maximum daily temperature for the same month

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Temperature
  - Airport Reference Temperature
    - $ART = Ta + \frac{1}{3}(Tm - Ta)$
    - T_a = Monthly mean of average daily temperature for the hottest month of the year
    - T_m = Monthly mean of the maximum daily temperature for the same month

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Temperature
  - Standard Temperature at an Elevation (in ºC)
    - STE = {Temp at MSL - rate of change of temp X elevation}
    - If 'h' is height above MSL in meters.
    - 'r' is rate of change of temperature with height or depth above MSL, is 0.0065ºC / m
    - Standard temperature at MSL is 15ºC, then
    - $STE = (15 - h \times r)$

BASIC RUNWAY LENGTH-FACTORS AFFECTING

- Temperature
  - Effect of Temperature
    - Air density reduces as the elevation increases which in turn reduces the lift on the wings of the aircraft.
    - Thus reduces drag on aircraft while landing or requires longer distance for producing necessary lift for the aircraft to fly.
    - **Increases basic runway length, the increase being 1% for every 1ºC rise in airport reference temperature above the standard temperature at that elevation. (ICAO)**

BASIC RUNWAY LENGTH

- Surface Wind
  - Head Wind
    - Provides breaking during landing.
    - Greater lift during take-off.
    - **Reduces runway length**

BASIC RUNWAY LENGTH

- Surface Wind
  - Tail Wind
    - Pushes the aircraft in forward direction
    - Generation of lift is difficult
    - **Increases runway length by a large value**

BASIC RUNWAY LENGTH

- Surface Wind
  - Cross Wind
    - It has two components, one along the aircraft and other transverse to the aircraft
    - The component along the aircraft may act as head wind or as tail wind
    - The component transverse to the aircraft produces sway in the movement of the aircraft. If it is very high then it may cause eccentric landing or take-off (away from air path)

BASIC RUNWAY LENGTH

- Cross Wind

BASIC RUNWAY LENGTH

- Location and Condition of Runway
  - Altitude
    - Affects air density, atmospheric pressure and temperature
      - The reduction in air density or atmospheric pressure with height above MSL affects the drag and lift forces and subsequent requirement of length of runway.
    - **Requires longer runway length, increase being 7% per 300m altitude above MSL**

BASIC RUNWAY LENGTH

- Location and Condition of Runway
  - Runway Gradient
    - Runway gradients are of two types:
      - Longitudinal gradient
      - Transverse gradient
    - Transverse gradient
      - Quick disposal of water from the pavement surface

BASIC RUNWAY LENGTH

- Location and Condition of Runway
  - Runway Gradient
    - Longitudinal gradient
      - If the gradient is steep it may cause pre-mature lift-off or may induce structural defects.
      - It will cause more consumption of energy, therefore, will require longer length of runway to attain the desired ground speed.

BASIC RUNWAY LENGTH

- Location and Condition of Runway
  - Runway Gradient
    - Effective longitudinal gradient
      - Average gradient, computed based on difference in maximum and minimum elevation along the runway and divided by the total length of runway.

    - **Runway length to be increased at a rate of 20% for every 1% of the effective gradient. (FAA)**

CORRECTIONS TO BASIC RUNWAY LENGTH

- Elevation correction
- Temperature correction and
- Gradient correction

  - **These corrections have to be applied in the same sequence as listed above**

CORRECTIONS TO BASIC RUNWAY LENGTH

- Elevation correction rate
  - L_e = 7% per 300m rise above MSL

- Temperature correction rate
  - L_t = 1% for every 1° rise in Airport Reference Temperature above standard Atmospheric temperature at that elevation

- Gradient correction rate
  - L_g = 20% for every 1% of effective gradient

CORRECTIONS TO BASIC RUNWAY LENGTH

- Procedure for calculating corrected length
  - Elevation correction
    - Find the required basic field runway length under standard conditions 'LB'
    - Calculate elevation correction rate 'L_e' and apply it to 'LB'
    - Add this value to 'LB'. Lets denote it as 'LE'.

CORRECTIONS TO BASIC RUNWAY LENGTH

- Procedure for calculating corrected length
  - Temperature Correction
    - Calculate airport reference temperature (ART)
    - Calculate standard temperature at the given elevation (ST).
    - Calculate temperature correction rate ‘L_t’ and apply it to ‘LE’.
    - Add this value to ‘LE’. Lets denote this corrected length as ‘LT’

CORRECTIONS TO BASIC RUNWAY LENGTH

- Procedure for calculating corrected length
  - Check on combined correction for temperature and elevation
    - Calculate percentage increase in length after the two corrections with respect to 'LB'. i.e. (L_t + L_e).
    - It is OK if less than and equal to 35%.
    - If it is more than 35% then model testing has to be carried out.

CORRECTIONS TO BASIC RUNWAY LENGTH

- Procedure for calculating corrected length
  - Gradient Correction
    - Calculate effective gradient, if not given.
    - Calculate gradient correction rate ‘L_g’ and apply it to ‘LT’.
    - Add this value to ‘LT’
    - This is the final corrected length of runway.

PROBLEMS

The data below refers to the daily temperature for the hottest month of the year for a given airport site. Determine the airport reference temperature.

Date	Temperature, °C		Date	Temperature, °C	
	Maximum	Average		Maximum	Average
1	42.5	25.5	16	43.7	26.2
2	42.5	25.5	17	43.8	25.8
3	42.7	25.7	18	44.0	26.3
4	43.0	25.9	19	44.8	26.3
5	43.0	25.9	20	44.1	26.3
6	43.0	25.9	21	44.3	26.5
7	42.8	25.8	22	44.3	26.9
8	43.0	25.9	23	44.5	26.5
9	43.0	25.9	24	44.6	26.6
10	43.1	25.0	25	44.6	26.9
11	43.3	26.3	26	44.7	27.0
12	43.5	26.4	27	44.6	27.0
13	43.3	26.3	28	44.7	27.0
14	43.5	26.4	29	44.8	26.2
15	43.6	26.3	30	45.0	27.2

Solution:

- Mean of the maximum daily temperature, $T_m = \frac{1312.3}{30} = 43.74°C$
- Mean of the average daily temperature, $T_a = \frac{787.4}{30} = 26.24°C$
- Airport Reference Temperature, $ART = Ta + \frac{1}{3}(Tm - Ta)$
- $ART = 32.07°C$

PROBLEMS

The following data refers to the proposed longitudinal section of runway.

End to End of Runway	Gradient
0.0 to 5.0 Chains	+1.0%
5.0 to 15.0 Chains	-1.0%
15.0 to 30.0 Chains	+0.8%
30.0 to 40.0 Chains	+0.2%

If one metric chain is of 20m length, determine the effective gradient of runway.

Solution:

Chainage	0	5	15	30	40
Elevation					

- Maximum difference in elevation = 101.8 – 99.0 = 2.8m
- Total runway length = 40 x 20 = 800m.
- Therefore, effective gradient of runway

$$= \frac{2.8}{800} \times 100\ percent$$

= 0.35 percent

PROBLEMS

The length of runway under standard conditions is 1620m. The airport site has an elevation of 270m. Its reference temperature is 32.94°C. If the runway is to be constructed with an effective gradient of 0.20 percent, determine the corrected runway length.

Solution:

1. Correction for elevation, $L_e = \frac{7}{100} \times 1620 \times \frac{270}{300} = 102m$

Corrected Length, LE = LB + Le = 1620 + 102 = 1722m.

2. Correction for temperature, L_t

3. Determination of standard atmospheric temperature at the given elevation, $STE = 15 - 270 \times 0.0065 = 13.25°C$. Rise of temperature = 32.94 – 13.25 = 19.69°C

Correction for temperature, $L_t = \frac{1}{100} \times 19.69 \times 1722 = 339m$

PROBLEMS

The length of runway under standard conditions is 1620m. The airport site has an elevation of 270m. Its reference temperature is 32.94°C. If the runway is to be constructed with an effective gradient of 0.20 percent, determine the corrected runway length.

Solution:

Corrected Length, LT = LE + Lt = 1722+339 = 2061m

Check for the total correction for elevation plus the temperature: Total correction in percentage =

(2061-1620/1620)*100 = 27.22%, According to ICAO, the value should be less than 35%.

4. Correction for gradient, $L_g = \frac{20}{100} \times 0.20 \times 2061 = 82.5m$

Corrected length = LT + Lg = 2061+82.5 = 2143.5m Approx = 2150m

RUNWAY GEOMETRIC

RUNWAY GEOMETRIC

- Length of runway
- Width of runway strip
- Sight Distance
- Longitudinal and Effective Gradient
- Rate of Change of Longitudinal Gradient
- Transverse Gradient
- Safety Area

RUNWAY GEOMETRIC

- Runway Length
  - Basic runway length depends up on the category in which the aircraft falls as per ICAO classification.
  - This length is modified for elevation, temperature and gradient correction.

RUNWAY GEOMETRIC

- Runway length requirements for various aircraft

Aircraft	Runway Length, m
Small airplanes with <10 passenger seats	
75% of fleet	750
95% of fleet	920
100% of fleet	1090
Small airplanes with 10 or more passenger seats	1270

RUNWAY GEOMETRIC

- Runway length requirements for various aircraft

Aircraft	Runway Length, m
Large airplanes of 60000 lb or less	
75% of fleet at 60% useful load	1615
75% of fleet at 90% useful load	2135
100% of fleet at 60% useful load	1680
100% of fleet at 90% useful load	2379

RUNWAY GEOMETRIC

- Runway Width
  - Depends upon the type of airport and largest aircraft in operation.
  - In case of large aircraft, the central 30m width of the runway pavement is observed to take more concentrated air-traffic load.
  - Also, it requires additional space on the two sides of this 30 m width so as to protect the possible damage to the farthest machinery i.e. engines from ingestion of loose material of shoulders.

RUNWAY GEOMETRIC

- Runway Width
  - As per ICAO (in meters)

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

RUNWAY GEOMETRIC

- Sight Distance
  - Generally no sight distance restrictions as the longitudinal gradients for the runway are quite gentle.
  - Hazardous locations are crossings of two runways or runway and taxiway.
  - Adherence to runway longitudinal gradient standards provides adequate line of sight

RUNWAY GEOMETRIC

- Sight Distance

Airport Category	Y (meter)	X
ICAO code letter A	1.5	Half runway length
ICAO code letter B	2.1	Half runway length
ICAO code letter C	3.0	Half runway length

RUNWAY GEOMETRIC

- Sight Distance
  - Runway grade should be such that any two points Y meters above runway centerline will be mutually visible for a minimum distance of X

RUNWAY GEOMETRIC

- Runway Gradient
  - Longitudinal and Effective gradient
    - The longitudinal gradient of runway increases the required runway length
    - It also affects the aircraft performance
    - These should be as flat as possible to avoid excessive engine thrust
    - ICAO limits the maximum longitudinal gradient to 1.25 to 1.5 percent for runways that serve the largest type of aircraft

RUNWAY GEOMETRIC

- Runway Gradient
  - Rate of change of Effective longitudinal gradient
    - The abrupt change may cause premature lift off of aircraft during take off
    - The change in gradient should be smooth through the provision of vertical curves
    - No vertical curve is required if the grade change is less than 0.4 percent

RUNWAY GEOMETRIC

- Runway Gradient
  - Rate of change of Effective longitudinal gradient

Type of Airport	**Max Longitudinal Gradient**	**Maximum Effective Gradient**
A, B, C	1.50%	1.00%
D, E	2.00%	2.00%

RUNWAY GEOMETRIC

- Runway Gradient
  - Rate of change of Effective longitudinal gradient (ICAO)

Type of Airport	**Rate of change/Distance between 30m length of curve and grade intersection**	
A, B	0.10%	< 300(a+b)m
C	0.20%	< 150(a+b)m
D, E	0.40%	< 50(a+b)m

‘a’ and ‘b’ are angle of interchange between grades

RUNWAY GEOMETRIC

- Runway Gradient
  - Rate of change of Effective longitudinal gradient (FAA)

Description	Small Airport	Large Airport
Maximum ‘a’ or ‘b’	2%	1.5%
Length of Vertical Curve L_1 or L_2 for each 1% grade change	90 m	300 m
Distance between points of intersection of grade line (D)	75(a+b)m	300(a+b)m

RUNWAY GEOMETRIC

- Transverse Gradient
  - Provided for quick disposal of surface water
  - Ponding of water is hazardous for aircraft operation
  - Minimum recommended transverse slope is 1%
  - For rigid pavement it can be kept as low as 0.5%

RUNWAY GEOMETRIC

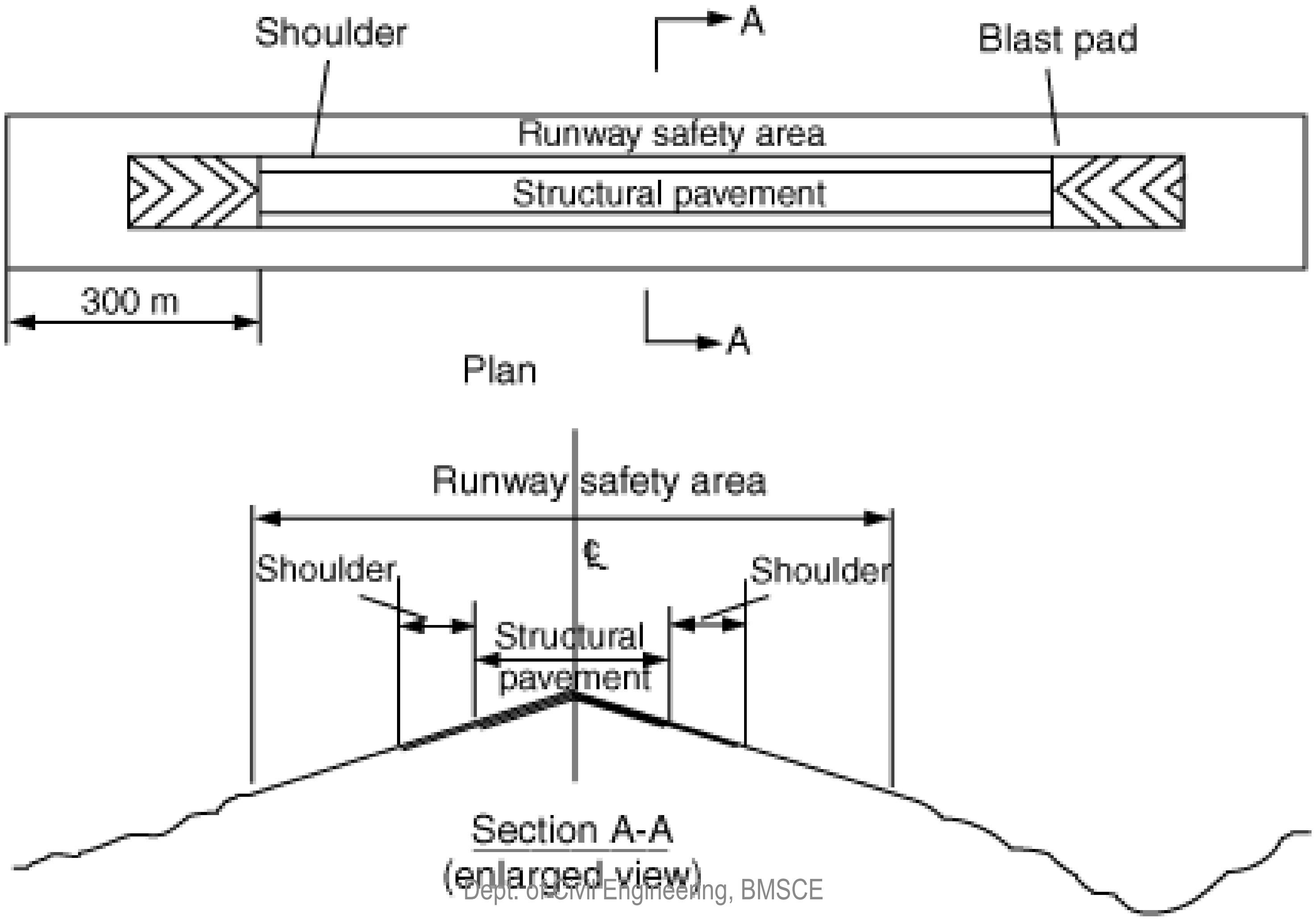
- Transverse Gradient
  - Slope upto 2% are permitted for runways that serve smaller classes of aircraft (Code A and B). For other runways, maximum transverse slope is 1.5%
  - For shoulders, slope of upto 5% is permitted

RUNWAY GEOMETRIC

- Safety Area
  - The runway safety area is an area which is cleared, drained and graded.
  - It includes the structural pavement, shoulders on either side of runway and the additional width.

RUNWAY GEOMETRIC

- Safety Area



RUNWAY GEOMETRIC

- Shoulders
  - These are usually lesser strength pavements and are provided on both sides of the runway strip.
  - They impart a sense of openness to the pilots.
  - Sometimes these are established to resist jet blast erosion or to accommodate maintenance equipment.
  - Shoulders for small airports may be turfed.

RUNWAY GEOMETRIC

- Shoulders
  - Shoulders are useful during emergency landing or takeoff.
  - These are not meant for regular application of load.