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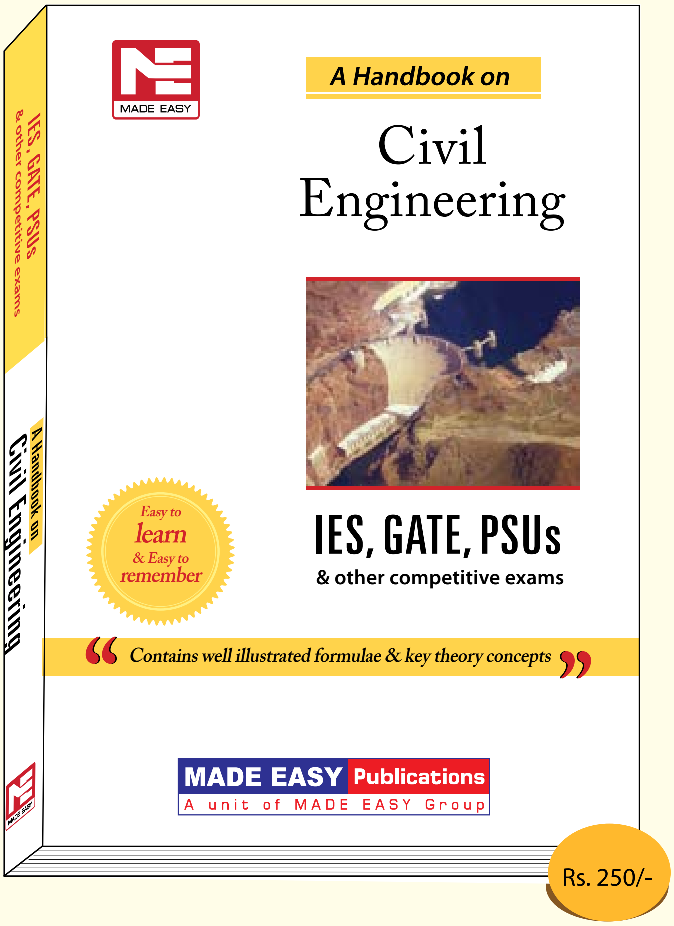
A handbook on Civil Engineering



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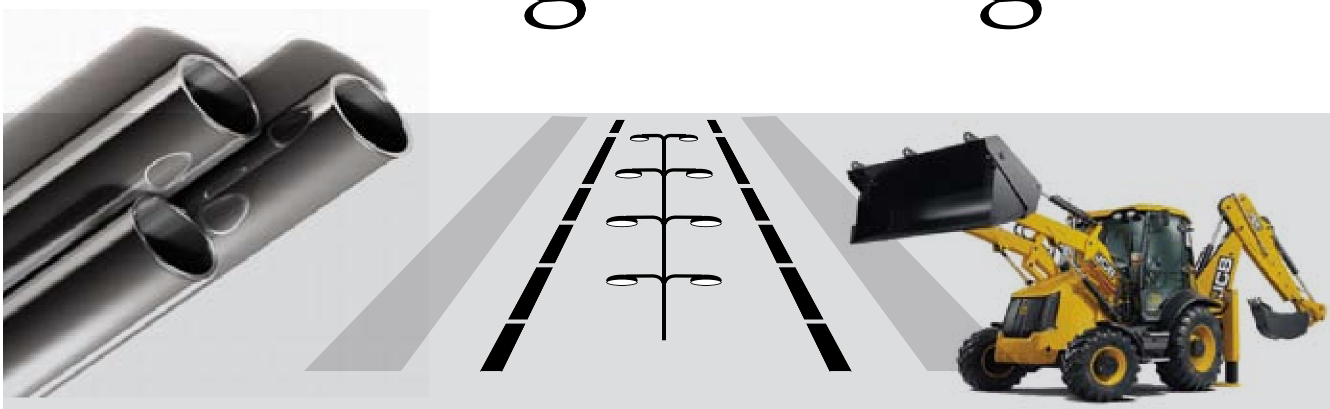
A Handbook on

Civil Engineering



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For

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& OTHER COMPETITIVE EXAMS

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Director's Message

B. Singh (Ex. IES)

During the current age of international competition in Science and Technology, the Indian participation through skilled technical professionals have been challenging to the world. Constant efforts and desire to achieve top positions are still required.

I feel every candidate has ability to succeed but competitive environment and quality guidance is required to achieve high level goals. At MADE EASY, we help you to discover your hidden talent and success quotient to achieve your ultimate goals. In my opinion IAS, IES, GATE & PSU's exams are tool to enter in to main stream of Nation serving. The real application of knowledge and talent starts, after you enter in to the working system. Here in MADE EASY you are also trained to become winner in your life and achieve job satisfaction.

MADE EASY aluminae have shared their winning stories of success and expressed their gratitude towards quality guidance of MADE EASY. Our students have not only secured All India First Ranks in IES, GATE and PSU entrance examinations but also secured top positions in their career profiles. Now, I invite you to become aluminae of MADE EASY to explore and achieve ultimate goal of your life. I promise to provide you quality guidance with competitive environment which is far advanced and ahead than the reach of other institutions. You will get the guidance, support and inspiration that you need to reach the peak of your career.

I have true desire to serve Society and Nation by way of making easy path of the education for the people of India.

After a long experience of teaching in Civil Engineering over the period of time MADE EASY team realised that there is a need of good *Handbook* which can provide the crux of Civil Engineering in a concise form to the student to brush up the formulae and important concepts required for IES, GATE, PSUs and other competitive examinations. This *handbook* contains all the formulae and important theoretical aspects of Civil Engineering. It provides much needed revision aid and study guidance before examinations.

B. Singh (Ex. IES)
Founder & Director, MADE EASY Group

CONTENTS

A Handbook on Civil Engineering

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Strength of Materials

CONTENTS

1. PROPERTIES OF METALS, STRESS AND STRAIN

IMPORTANT MECHANICAL PROPERTIES

- Elasticity

  It is the property by virtue of which a material deformed under the load is ***enabled*** to return to its original dimension when the load is removed.

> **Remember**
>
> If body regains ***completely*** its original shape it is called ***perfectly*** elastic body
>
> ***Elastic limit*** marks the ***partial*** break down of elasticity beyond which removal of load result in a degree of ***permanent deformation***.
>
> Steel, Aluminium, Copper, may be considered to be perfectly elastic ***within certain limit***.

- Plasticity

  The characteristics of the material by which it undergoes ***inelastic strain*** beyond those at the ***elastic limit*** is known as plasticity.

> **Remember**
>
> This property is particularly useful in operation of ***pressing*** and ***forging***.
>
> When large deformation occurs in a ***ductile*** material loaded in ***plastic*** region, the material is said to undergo ***plastic flow***.

- Ductility

  It is the property which permits a material to be drawn out ***longitudinally*** to a reduced section, under the action of ***tensile force***.

> **Remember**
>
> A ductile material must posses a high degree of plasticity and strength.
>
> Ductile material must have ***low*** degree of elasticity.
>
> This is useful in ***wire drawing***.

- Brittleness

  It is lack of ductility. Brittleness implies that it can ***not*** be drawn out by tension to smaller section

> **Remember**
>
> In brittle material failure take place under load ***without*** significant deformation.

Ordinary ***Glass*** is nearly ***ideal*** brittle material.
Cast iron, ***concrete*** and ceramic material are brittle material.

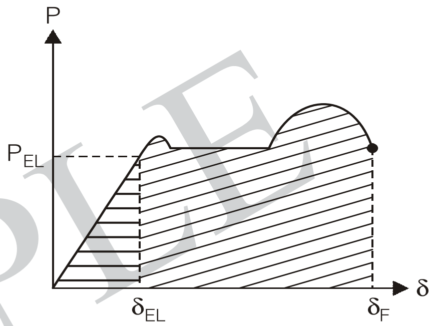
- **Malleability**

  It is the property of a material which permits the material to be ***extended*** in ***all direction*** without rupture.

Remember: A malleable material posses a ***high degree*** of plasticity, but ***not*** necessarily ***great strength***.

- **Toughness**

  It is the property of material which enables it to absorb energy ***without fracture***.



Remember: It is desirable in material which is subjected to ***cyclic*** or ***shock loading***.

It is represented by area under ***stress-strain*** curve for material upto fracture.

Bend test used for common comparative test for toughness.

- **Hardness**

  It is the ability of a material to resist ***indentation*** or ***surface abrasion***.

Remember: Brinnell hardness test is used to check hardness.

$$\text{Brinnell hardness number} = \frac{P}{\frac{\pi D}{2}\left[D - \sqrt{D^2 - d^2}\right]}$$

Here, P = Standard load
D = Diameter of steel ball (mm)
d = Diameter of indent (mm)

- **Strength**

  This property enables material to resist fracture under load.

Remember: This is most important property from ***design*** point of view.
Load required to cause fracture, divided by area of test specimen, is termed as ***ultimate strength***.

STRESS AND STRAIN

STRESS (N/m²)

It is the resistance offered by the body to deformation

- Nominal stress (Engineering stress) $= \dfrac{\text{Load}}{\text{Original Area}}$
- Actual/True stress $= \dfrac{\text{Load}}{\text{Changed (Actual) Area}}$

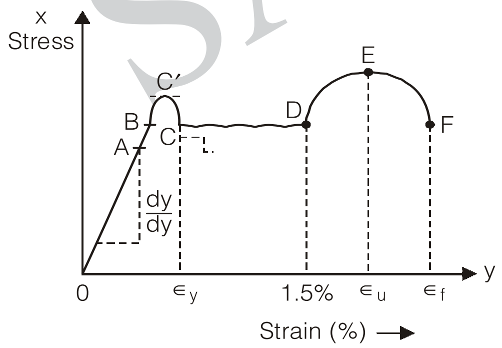
STRAIN

Deformation per unit length in the direction of deformation is known as strain.

Strain $= \dfrac{\Delta L}{L}$

It is a ***diamensionless*** quantity.

ENGINEERING STRESS-STRAIN CURVE OF MILD STEEL FOR TENSION UNDER STATIC-LOADING



OA — Straight line (proportional region, ***Hooke's law is valid***)
OB — Elastic region
BC — Elasto plastic region
CD — Perfectly plastic region
DE — Strain hardening
EF — Necking region
A — Limit of proportionality
B — Elastic limit
C — Lower yield point
F — Fracture point

C′ — Upper yield point
D — Strain hardening starts
E — Ultimate point or maximum stress point

- **Limit of Proportionality**
  It is the stress at which the stress-strain curve ***ceases*** to be a straight line.

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Soil Mechanics

CONTENTS

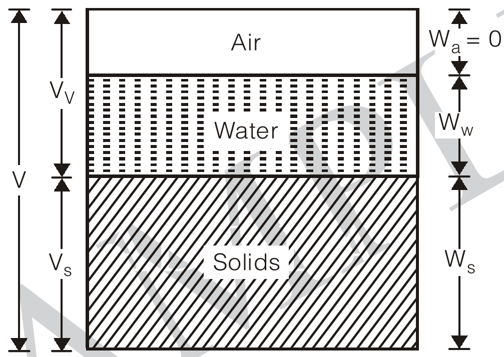
1. PROPERTIES OF SOILS

PHASE DIAGRAM

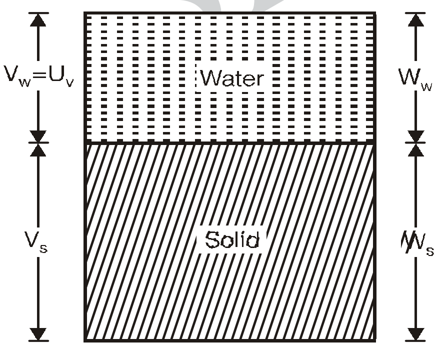
Soil mass is in general a three phase system composed of solid, liquid and gaseous matter.

The diagrammatic representation of the different phases in a soil mass is called the "phase diagram".

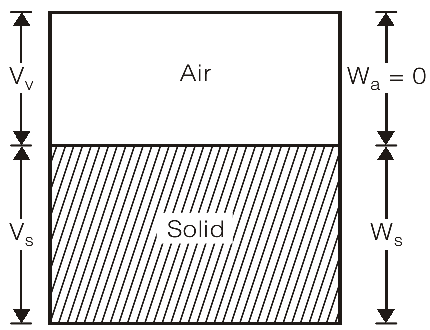
A 3-phase system is applicable for partially saturated soil whereas, a 2-phase system is for saturated and dry states of soil.



3-Phase: (Partially Saturated)



2-Phase (Saturated)



2-Phase (Dry)

WATER CONTENT

$$w = \frac{W_w}{W_s} \times 100$$

where, W_w = Weight of water

W_s = Weight of solids

There can be no upper limit to water content, i.e., $w \geq 0$

VOID RATIO

$$e = \frac{V_v}{V_s}$$

where, V_v = Volume of voids
V_s = Volume of solids.

Void ratio of fine grained soils are generally higher than those of coarse grained soils.

In general $e > 0$ i.e., no upper limit for void volume.

POROSITY

$$n = \frac{V_v}{V} \times 100$$

where, V_v = Volume of voids
V = Total volume of soil

Porosity cannot exceed 100% i.e.,
$0 < n < 100$

> **NOTE:** In comparison to porosity, void ratio is more frequently used because volume of solids remains same, whereas total volume changes.

DEGREE OF SATURATION

$$S = \frac{V_w}{V_v} \times 100$$

where, V_w = volume of water
V_v = Volume of voids

$0 \leq S \leq 100$
for perfectly dry soil : $S = O$
for Fully saturated soil : $S = 100\%$

AIR CONTENT

$$a_c = \frac{V_a}{V_v} = 1 - S$$

UNIT WEIGHT

(a) Bulk unit weight

$$\gamma = \frac{W}{V} = \frac{W_s + W_w}{V_s + V_w + V_a}$$

Thus Bulk unit weight is total weight per unit volume.

(b) **Dry Unit Weight** is the weight of soil solids per unit volume.

$$\gamma_d = \frac{W_s}{V}$$

- Dry unit weight is used as a measure of denseness of soil. More dry unit weight means more compacted soil.

(c) **Saturated unit weight:** It is the ratio of total weight of fully saturated soil sample to its total volume.

$$\gamma_{sat} = \frac{W_{sat}}{V}$$

(d) **Submerged unit weight**

Q_r Buoyant unit weight (γ'). It is the submerged weight of soil solids per unit volume.

- γ' is roughly 1/2 of saturated unit weight.

SPECIFIC GRAVITY

- Specific gravity of soil solids (G) is the ratio of the weight of a given volume of solids to the weight of an equivalent volume of water at 4°C.

$$G = \frac{W_s}{V_s \cdot \gamma_w} = \frac{\gamma_s}{\gamma_w}$$

- **Apparent or mass specific gravity (G_m):** Mass specific gravity is the specific gravity of the soil mass and is defined as the ratio of the total weight of a given mass of soil to the weight of an equivalent volume of water.

$$G_m = \frac{W}{V\gamma_w} = \frac{\gamma}{\gamma_y}$$

SOME IMPORTANT RELATIONSHIPS

(i) Relation between W_s, W and w:

$$W_S = \frac{W}{1 + w}$$

(ii) Relation between e and n

$$n = \frac{e}{1 + e} \quad \text{or} \quad e = \frac{n}{1 - n}$$

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Engineering Hydrology

CONTENTS

1. PRECIPITATION AND GENERAL ASPECTS OF HYDROLOGY

INDEX OF WETNESS

- $$\text{Index of wetness} = \frac{\text{rainfall in a given year at a given place}}{\text{average annual rainfall of that place}} \times 100$$
- % Rain deficiency = 100 – % Index of wetness

ARIDITY INDEX

- $$A.I = \frac{PET - AET}{PET} \times 100$$

where, A.I. = Aridity Index
PET = Potential Evapo-transpiration
AET = Actual Evapotranspiration

(a) $AI \le 0 \rightarrow$ Non arid
(b) $1 \le A.I \le 25 \rightarrow$ Mild Arid
(c) $26 \le A.I \le 50 \rightarrow$ Moderate Arid
(d) $A.I > 50 \rightarrow$ Severe Arid.

Remember: In this AI calculation, AET is calculated according to Thornthwite's water balance technique.

OPTIMUM NUMBER OF RAIN GAUGE : (N)

$$N = \left(\frac{C_v}{E}\right)^2 \rightarrow C_v = \frac{100\sigma}{\bar{P}}$$

$$\bar{P} = \frac{P_1 + P_2 + \ldots + P_n}{n}$$

$$\sigma = \sqrt{\left(\frac{n}{n-1}\right)\left(\overline{p^2} - \bar{p}^2\right)}$$

$$\overline{P^2} = \frac{P_1^2 + P_2^2 + P_n^2}{n}$$

where, C_v = Coefficient of variation, E = Allowable % Error,
σ = Standard deviation, n = Number of stations

ESTIMATION OF MISSING RAINFALL DATA

(a) $$P_x = \frac{P_1 + P_2 + \ldots + P_n}{(n-1)}$$ If $N_1, N_2 \ldots N_n < 10\%$ of N_x

where, $N_1, N_2, \ldots N_x \ldots N_n$ are normal annual precipitation of 1, 2, ... x ... n respectively.

$P_1, P_2 \ldots P_n$ are rainfall at station 1, 2, ... n respectively.

and P_x is the rainfall of station x.

Case : A minimum number of three stations closed to station 'x'

$$P_x = \frac{P_1 + P_2 + P_3}{3}$$

(b) $$P_x = \frac{N_x}{n-1}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \ldots + \frac{P_n}{N_n}\right]$$

If any of $N_1, N_2, N_3 \ldots N_n > 10\%$ of N_x.

MEAN RAINFALL DATA

To convert the point rainfall values at various stations into an average value over a catchment the following three methods are in use

(i) Arithmetic Avg Method: When the rainfall mesaured at various stations in a catchment show little variation, the average precipitation over the catchment area is taken as the arithmetic mean of the station values.

$$P_{avg} = \frac{P_1 + P_2 + \ldots + P_n}{n}$$

where, $P_1, P_2 \ldots P_n$ are rainfall values of station 1, 2, ... n respectively.

In practice this method is used very rarely.

(ii) Thiessen Polygon Method: In this method the rainfall recorded at each station is given a weightage on thebasis of an area closest to the station.

$$P_{avg} = \frac{P_1A_1 + P_2A_2 + \ldots + P_nA_n}{A_1 + A_2 + \ldots + A_n}$$

where, $P_1, P_2, \ldots P_n$ are the rainfall data of areas $A_1, A_2 \ldots A_n$.

The Thiessen-polygon method of calculating the average percipitation over an area is superior to the arithmetic average method.

(iii) Isohyetal Method: An isohyet is a line joining points of equal rainfall magnitude. The recorded values for which areal average P is to be determined are then marked on the plot at appropriate stations. Neighbouring stations outside the catchment are also considered.

$$P_{avg} = \frac{A_1\frac{(P_1 + P_2)}{2} + A_2\frac{(P_2 + P_3)}{2} + \ldots A_{n-1}\frac{(P_{n-1} + P_n)}{2}}{A_1 + A_2 + \ldots + A_{n-1}}$$

■■■

2. EVAPORATION AND ITS MEASUREMENT

Evaporation is a cooling process in which heat of evaporation of about 585 cal/gm is provided by the water body. In this process liquid changes into gaseous phase of free surface.

DALTON'S LAW

The rate of evaporation is proportional to the difference between the saturation vapour pressure at the water temperature, e_s and the actual vapour pressure in the air, e_a. Thus

$$\boxed{E = K(e_s - e_a)}$$

where, E = Rate of evaporation

e_s = Saturation vapour pressure of air

e_a = Actual vapour pressure of air

$$\boxed{e_s - e_a = \text{Saturation defficiency}}$$

MEASUREMENT OF EVAPORATION

(i) ISI Standard Pan

$$\boxed{\text{Lake evaporation} = C_p \times \text{Pan evaporation}}$$

where, C_p = Pan coefficient

= 0.8 for ISI pan

= 0.7 for class-A pan

(ii) Empirical Evaporation Equations (Meyer's Formula)

$$\boxed{E = k_m(e_s - e_a)\left[1 + \frac{V_9}{16}\right]}$$

where k_m = Coefficients which accounts for size of water body.

= 0.36 (for large deep water)

$\simeq$ 0.50 (for small and shallow waters)

e_s = Saturation vapour pressure of air in mm of Hg.

e_a = Actual vapour pressure of overlying air in mm at Hg at specified height of 8 m.

V_9 = Monthly mean wind velocity in km/hr at about 9m above the ground level.

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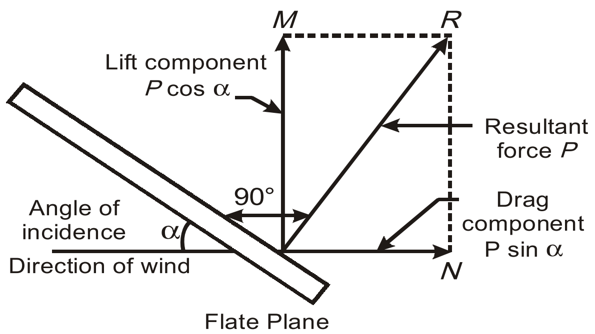
Airport, Dock, Harbour & Tunnelling Engineering

CONTENTS

1. AIRCRAFT CHARACTERISTICS AND PLANNING

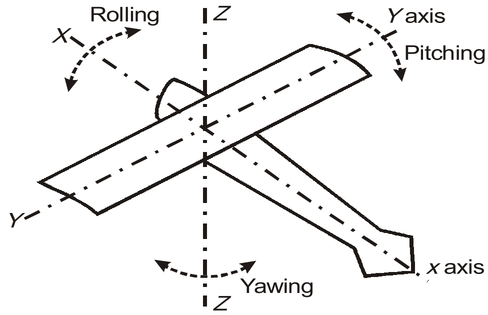
AEROPLANE COMPONENT PARTS

- Engine
  - (i) **Piston engine:** is driven by propeller.
    Suitable to operate at low altitudes and moderate speeds.
  - (ii) **Turbojet:** efficiency is higher at high altitudes owing to the drop in the atmospheric density and greater temperature difference through the turbine.
  - (iii) **Turbo Prop:** performs well at low altitudes as well as high altitude.
  - (iv) **Ram jet:** no moving parts, must be operated at high speed.
  - (v) **Rocket engine:** no limit on altitude since oxygen in the atmosphere is not relied upon for combustion. Engine carries its own supply of oxygen.
- Fuselage
  - main body of the aircraft
  - provides for power plant, fuel, cockpit, passengers, cargo etc.
- **Wings:** The purpose of an aircraft wing is to support the machine in the air when the engine has given it the necessary forward speed.



NOTE: As the angle of incidence increase, the drag component also increases and the lift component reduces.

- Three control



- The movement of aircraft about the *X*-axis is called rolling movement.
- The movement about y and z axes are called pitching and yawing movements respectively.
- **Elevator:** controls the pitching or up and down movements of the aircraft.
- **Rudder:** It is used for turning or yawing movement of the aircraft.
- **Aileron:** It is used to control of rolling movement about longitudinal axis.

AIRPORT PLANNING

- The regional plan usually provides the following information:
  1. Approximate locations of the airports in national map.
  2. Classification of airports
  3. Location of air strips
  4. Routes of air Travel.
- Following data is collected for regional planning:
  1. Population
  2. Topographical and geographical features
  3. Existing airports in the vicinity
  4. Air traffic characteristics
- Minimum spacings from existing airports:
  (i) for Airports serving small general aviation aircrafts under VFR conditions = 3.2 km (2 Miles)
  (ii) for airports serving bigger aircrafts under VFR conditions = 6.4 km (4 Miles)
  (iii) for airports operating piston engine aircrafts under IFR conditions = 25.6 km (16 Miles)
  (iv) for jet aircrafts under IFR conditions = 160 km (100 Miles)

  The best location is a site adjacent to the main highway.

■■■

2. RUNWAY DESIGN

ORIENTATION

- Runway is usually oriented in the direction of prevailing winds.
- The head wind i.e. the direction of wind opposite to the direction of landing and take off, provides greater lift on the wings of the aircraft when it is taking off.
- Cross wind component = V sin θ where θ = Angle of wind direction to runway centreline
- Normal component of the wind is called Cross wind component.
- The maximum permissible cross wind component depends upon the size of aircraft and the wing configuration.

Airports Serving	Max. limit of C.W.C.
1. For small aircrafts.	15 kmph
– for mixed traffic	25 kmph
2. For big Aircrafts	35 kmph

BASIC RUNWAY LENGTH

It is the length of runway under the following assumed conditions at the airport:

1. Airport altitude is at sea level
2. Temperature at the airport is standard (15°C)
3. Runway is levelled in the longitudinal direction.
4. No wind is blowing on runway.
5. Aircraft is loaded to its full loading capacity.
6. There is no wind blowing enroute to the destination.
7. Enroute temperature is standard.

CORRECTIONS FOR ELEVATION, TEMPERATURE AND GRADIENT

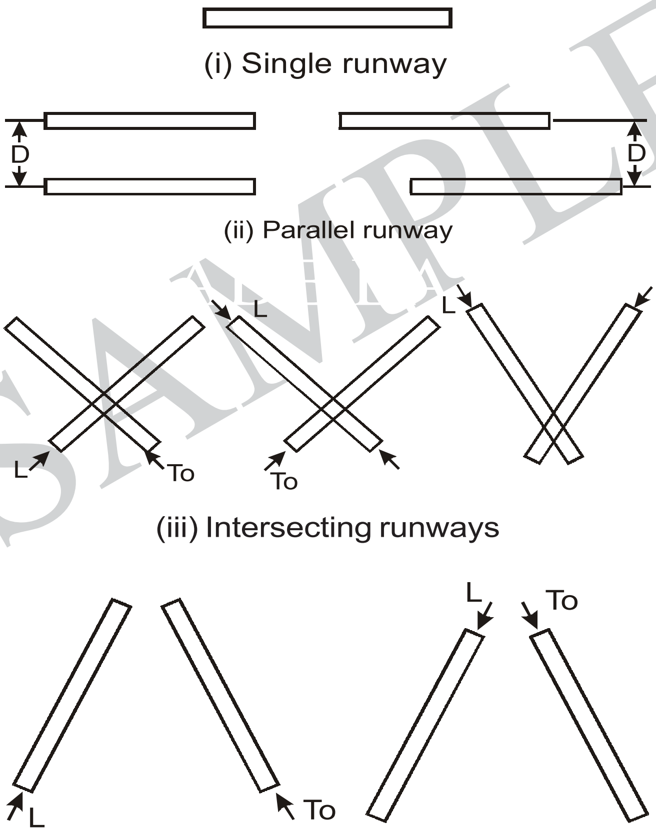
(a) **Correction of Elevation:** Basic runway length is increased at the rate of 7% per 300 m rise in elevation above the mean sea level.

3. AIRPORT CAPACITY AND TUNNELING AREA

AIRPORT CAPACITY

- The number of aircraft movements which an airport can process within a specified period of time with an average delay to the departing aircraft within the acceptable time limit is defined as airport capacity.
- The following factors affect the airport operating capacity:

  Runway configurations and the connected taxiways



L = Landing T.o. = Taking off.

- **Single Runway:** is usually adopted when the wind blows in one direction for most of the time in a year and air traffic requirement does not exceed the capacity of such pattern.