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ગુજરાત ગૌણ સેવા પસંદગી મંડળ (GSSSB)
ના અદ્યતન અભ્યાસક્રમ આધારિત

વર્ક આસિસ્ટન્ટ

વર્ગ-3

(For Civil Engineering)



સંપાદક

ધવલ મારૂ , પિનાકીન મારૂ



દાદાને અર્પણ


માતા-પિતાના ચરણોમાં અર્પણ
“જેમના આશીર્વાદથી સપનાઓને પાંખો મળી,
જેમની પ્રાર્થનાથી દરેક પગલે હિંમત મળી,
જેમના ત્યાગ અને સંસ્કારોએ જીવનને સાચી દિશા આપી—
એવા મારા પૂજનીય માતા-પિતાને
આ પુસ્તક હૃદયપૂર્વક અર્પણ.”
આપના આશીર્વાદ સદા સાથે રહે
મારા જીવનની દરેક સફળતાના પ્રથમ હકદાર
મારા માતા-પિતા.

પ્રસ્તાવના

"સફળતા એ માત્ર સપનું જોવાથી નહીં, પરંતુ યોગ્ય દિશામાં કરેલી સતત મહેનત અને મક્કમ સંકલ્પથી પ્રાપ્ત થાય છે."

સ્પર્ધાત્મક પરીક્ષાની તૈયારી એ માત્ર જ્ઞાન મેળવવાની પ્રક્રિયા નથી, પરંતુ પોતાના સપનાઓને સાકાર કરવાની એક મહત્ત્વપૂર્ણ સફર છે. ભારત સરકાર તથા ગુજરાત સરકાર દ્વારા આયોજિત AAE (Additional Assistant Engineer), Work Assistant તથા અન્ય ટેક્નિકલ ભરતી પરીક્ષાઓમાં સફળતા મેળવવા માટે યોગ્ય માર્ગદર્શન, સચોટ અભ્યાસસામગ્રી અને નિયમિત મહેનત અત્યંત આવશ્યક છે. આ હેતુને ધ્યાનમાં રાખીને લક્ષ્યમ એકેડેમી દ્વારા આ પુસ્તક આપ સમક્ષ રજૂ કરતાં અમને આનંદ થાય છે.

આ પુસ્તકનો મુખ્ય ઉદ્દેશ્ય સિવિલ એન્જિનિયરિંગ (Civil Engineering) ના જટિલ ટેક્નિકલ વિષયોને સરળ, સુવ્યવસ્થિત અને પરીક્ષાલક્ષી સ્વરૂપમાં રજૂ કરવાનો છે, જેથી વિદ્યાર્થીઓ આત્મવિશ્વાસ સાથે પોતાની તૈયારીને વધુ મજબૂત બનાવી શકે.

આ પુસ્તકમાં Geotechnical Engineering, Hydrology, Irrigation Engineering, Building Material & Construction, RCC, Steel Structure, Surveying, Fluid Mechanics, Highway Engineering, Railway, Bridge, Environment Engineering, CPM & PERT, AutoCAD સહિત કુલ 24 મહત્ત્વપૂર્ણ પ્રકરણોનો સમાવેશ કરવામાં આવ્યો છે, જે ટેક્નિકલ વિષયોની અસરકારક તૈયારીમાં ઉપયોગી બની રહેશે.

અમારો વિશ્વાસ છે કે યોગ્ય અભ્યાસસામગ્રી, સતત પ્રેક્ટિસ અને આત્મવિશ્વાસ એ સફળતાના મજબૂત પાયા છે. આ પુસ્તક આપની મહેનતને યોગ્ય દિશા આપવામાં અને સરકારી નોકરી મેળવવાના લક્ષ્ય તરફ આગળ વધવામાં ઉપયોગી સાથી બની રહે તેવો અમારો પ્રયાસ છે. પુસ્તકને વધુ ગુણવત્તાસભર બનાવવા માટે આપનાં સૂચનો અને અભિપ્રાયો હંમેશાં આવકાર્ય છે.

અંતે, દરેક વિદ્યાર્થીને એટલું જ કહેવા માગીએ છીએ કે "તમારું લક્ષ્ય મોટું રાખો, મહેનત પર વિશ્વાસ રાખો અને સફળતા ન મળે ત્યાં સુધી પ્રયત્નશીલ રહો." આપની મહેનત અને અમારું માર્ગદર્શન આપને ઉજ્જવળ ભવિષ્ય તરફ દોરી જાય તેવી હાર્દિક શુભેચ્છાઓ.

"લક્ષ્ય તમારું, સંકલ્પ અમારો – સફળતા તરફ સાથે એક મજબૂત પગલું."

સંપાદક

- ધવલ મારૂ
- પિનાકીન મારૂ

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-: કાયદાકીય જોગવાઈ :-

1) આ પુસ્તક પ્રકાશિત તમામ માહિતી તપાસવામાં આવી છે પણ જો કોઈ ભૂલ કે ટાઈપીંગ ભૂલ રહી જાય તો કોઈ વ્યક્તિ કે સંસ્થાને પહોચેલ ક્ષતિ માટે પ્રકાશક કે લેખક જવાબદાર નથી.
2) કોપીરાઇટના તમામ વિવાદ રાજકોટ ન્યાયિક ક્ષેત્રમા સુનવણી કરવામાં આવશે.
3) પુસ્તકમાં રહેલી ક્ષતિ માટે 9429077607 પર વોટ્સએપ કરવા નમ્ર વિનંતી.

કિંમત :- ₹ 699/-

આ પુસ્તકના લખાણનો કોઈપણ ભાગ, લેખનશૈલી, રજૂઆત શૈલી, મુદ્દાઓ અને તેની ગોઠવણી વગેરેનો ઈલેક્ટ્રોનિક, યાંત્રિક, ઝેરોક્ષ, પેમ્પલેટ, ટેસ્ટ પેપર, મુદ્રણ કે અન્ય કોઈપણ સ્વરૂપમાં ઉપયોગ પ્રકાશકની લેખિત પરવાનગી વિના કરવો નહીં. આવુ કૃત્ય ગેરકાયદેસર ગણાશે અને તેમ કરનારની સામે કાનૂની કાર્યવાહી કરવામાં આવશે તેની ખાસ નોંધ લેવી.
ઉપલબ્ધ માહિતીના આધારે આ પુસ્તકને ક્ષતિરહિત બનાવવાનો પૂરો પ્રયત્ન કરવામાં આવ્યો છે તેમ છતાં સંપાદન અને મુદ્રણ સમયે માનવસહજ ભૂલ કે ચૂકને કારણે કોઈ ક્ષતિ રહી જવા પામી હોય તો તેની કોઈપણ જવાબદારી લેખક કે પ્રકાશકની રહેશે નહીં. આ પુસ્તકનો ઉપયોગ કરવાને કારણે તેમાં થયેલી ભૂલચૂકને કારણે કોઈપણ વ્યક્તિને કદાચ કોઈપણ રીતે નુકસાન કે ક્ષતિ થાય તો તેનું ઉત્તરદાયિત્વ લેખક કે પ્રકાશનનું રહેશે નહીં. આ પુસ્તકનો કોઈપણ જીવિત અથવા મૃત વ્યક્તિ કે વાસ્તવિક ઘટનાઓ સાથે કોઈ સમાનતા કે સંબંધ એ સંયોગ માત્ર છે, તથા તેનો હેતુ કોઈપણ વ્યક્તિ, સમુદાય, સંપ્રદાય, ધર્મ કે ધાર્મિક લાગણીને દુભાવવાનો નથી.
નોંધ: કોઈપણ વિવાદ રાજકોટ ન્યાયક્ષેત્રને આધીન રહેશે.

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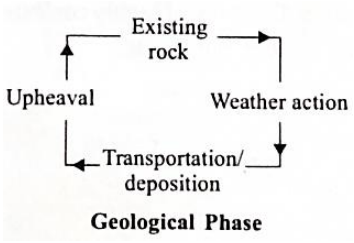
UNIT : 1 Geotechnical Engineering

Chapter 1 : Soil Origin & Its Properties

- Father of Soil Mechanics **Dr. Karl Terzaghi** coined the term "Soil Mechanics" in 1925.
- A civil Engineer is concerned mainly with (10-15) m from top crust of soil in dealing with small or medium size project.
- The soil particles coarser than 0.075 mm are visible to the naked eye

$$\textbf{Specific Surface} = \frac{Surface}{Mass\ or\ volume}$$

- The specific surface is defined as the total area of surface of grains per unit of mass. A sphere has least specific surface area as compared to a plate.



Geological Phase

Erosion phase	
Physical weathering	**Chemical weathering**
• Retains same composition of Parent rock	• Change in mineral composition
• Bulky particles like as gravel, sand	• Plate like structure with high surface area, ex- clay, silt
• Shape-Angular, Rounded, Flat & Elongated	• Crystalline particle of colloidal size known as clay mineral
• Single grain particles without bonding between them	

Soil	Deposited by
Alluvial Soil	River/running water
Marine Soil	Sea water
Lacustrine Soil	Still water like as lakes
Acolian Soil	Wind like as Sand-dunes, Loess
Glacial Soil	Ice (Till/drift)

- **Special Points:**
  - Loess is a wind deposit soil (silt). It is generally of uniform gradation, with the particle size between 0.01-0.05 mm. These deposits have low density & high compressibility (when they are in wet form). For loess the permeability in vertical direction is generally larger than that of horizontal direction.
  - Soil deposit due to gravity force is called talus (colluvial soil).
- **Various types of Soil**
  - Alluvial soil: Low density & liable to liquefaction in earthquake prone areas.
- **Black cotton soil:** Residual deposits form basalt or trap rocks, contain clay mineral. Very poor bearing capacity (50-100 kN/m²).
  - If depth of layer of B.C.S. is shallow, Then remove its layer for making structure.
  - If depth of layer of BCS is Deep, then we use under-reamed piles In foundation for making structure.
  - Generally we use raft foundation in black cotton soil.

- Black cotton soil have high shrinkage & swelling characteristics, it's shearing strength is extremely low, It is due to Montmorillonite mineral.

➢ **Laterite soil:** Iron oxide gives red or pink colour. It is residual soil formed from basalt. It is soft & can be cut with knife.

➢ **Desert soil:** It is uniform in gradation (ex. dune sand). It is Non-plastic & highly pervious.

➢ **Loam:** It is the mixture of sand, silt & clay.

➢ **Caliche:** It is the mixture of gravel, sand & silt.

➢ **Marine soil:** It has low shearing strength, highly compressible, soft & highly plastic.

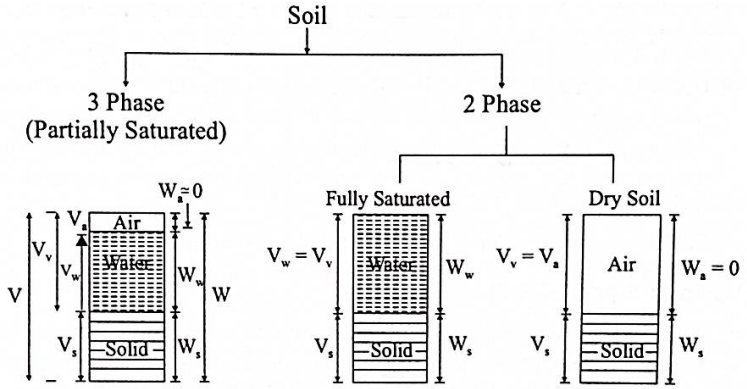
➢ **Peat:** It is the organic soil with fibrous aggregates formed from vegetable matter in excess moisture (ex. in swamps), highly compressible. It is not suitable for foundation.

➢ **Bentonite:** It is formed from volcanic ash. It has high percentage of Montomorillonite.

➢ **Special Point:** Lithification is a process by which unconsolidated materials are converted into coherent solid rock due to compaction or cementation action.

➢ **Phase diagram**

- It is the diagrammatic representation of the different phases in a soil mass.



➢ **Special Point:** If the voids absent in a system, it would not be termed soil.

- **Ex:-** Granite (Aquifuge rock).
- If the voids of a soil are completely filled with air, then it is known as dry soil.

➢ **Water content**

$$\mathbf{W} = \frac{W_w}{W_s} \times 100$$

- There is no upper limit for it ($W \geq 0$)

➢ **Void ratio**

$$\mathbf{e} = \frac{V_v}{V_S}, 0 < e < Infinity$$

- Fine grained soil have higher Void ratio than coarse grained soil. But the size of void in coarse grained soil is greater than fine grained soil.

➢ **Porosity**

$$\mathbf{N} = \frac{V_v}{V} \times 100, 0 < n < 100\%$$

➢ **Special Points:** For uniformly graded coarse soil having perfectly spherical grain size when particles are arranged in

(a) Prismoidal array, e min =35% n min =25.9%

(b) Cubical array, e max =91%. n max = 47.6%

- Void ratio is much better as compared to porosity because porosity is define with respect to total volume but void -ratio w.r.t. volume of soild.
- Generally value of porosity is less than void ratio for same soil sample

➢ **Degree of Satuaration**

$$\mathbf{S} = \frac{V_w}{V_v}, 0 \leq S \leq 100\%$$

- for fully saturated soil at shrinkage S = 100%

- For partially saturated soil 0 < s < 100
- for fully dry soil S = 0%

Soil Condition	S (%)
Dry Soil	0
Humid Soil	0-0.25
Damp Soil	0.25-0.5
Moist Soil	0.5-0.75
Wet Soil	0.75-1
Fully Saturated	1

Air Content

$\text{Ac} = \frac{V_a}{V_v}, (0 \leq a_c \leq 1)$

Percentage air Void

$\text{na} = \frac{V_a}{V} \times 100, (0 \leq \eta a < 1)$

➢ **Special point :** $\text{na} = \text{n} \times ac, ac + s = 1, (ac > nc)$

- **Bulk unit weight**

$$\gamma, = \frac{W}{V} = \frac{W_s + W_w}{V_s + V_w + V_a}, \quad \text{units} \longrightarrow \frac{KN}{m^3}, \frac{N}{m^3}, \frac{kgf}{cm^3}$$

- **Unit weight of water**

$$\gamma_w = \frac{W_w}{V_w}$$

- Value of y changes with temperature but usually we take
- Y= 9.81 KN/m³ at 4°C

➢ **Unit weight of solid**

$$\boldsymbol{\gamma s = \frac{W_s}{V_s}, \quad \gamma s = G\gamma_w}$$

- where G = specific gravity of soil solid

➢ **Dry unit weight**

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

- High value of gamma γ_d indicates more compacted soil/Dense sand.

➢ **Submerged or Buoyant unit weight**

- When the soil is below the water table, then a Buoyant force acts upward on the soil solid & its saturated weight is decreased by unit weight of water.

$$\boldsymbol{\gamma_{sub} = \gamma_{sat} - \gamma_w}$$

➢ **Special Point:** Saturated soil may or may not be submerged but a submerged soil will always be saturated.

➢ **Saturated unit weight**

$$\boldsymbol{\gamma_{sat} = \frac{Wt.of\ saturated\ soil}{Volume\ of\ Soli}}$$

- It is the unit weight of soil when all the air voids are filled with water

➢ **Specific gravity of solids**

$$\mathbf{G} = \frac{\gamma_s}{\gamma_w} \textbf{ (Unitless)}$$

- It is measured at 27°C by pycnometer method. Also known as "Absolute specific gravity" or 'grain specific gravity.

➢ **Specific gravity:** G = 2.6 to 2.80 for Inorganic soil, G = 1.2 to 1.4 for organic soil

$$\mathbf{G} \propto \boldsymbol{mineral\ content}, \propto \frac{1}{\boldsymbol{amount\ of\ organic\ content}}$$

$$\boldsymbol{G_{fine\ grained}} > \mathbf{G_{coarse\ grained\ soil}}$$

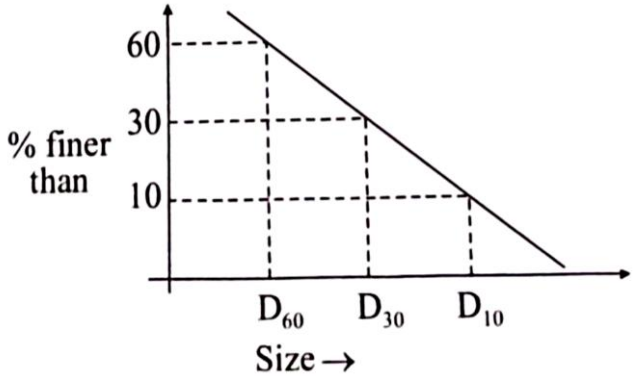
Chapter 2 : Index Properties of Soil

- Properties which help to access the engineering behaviour of soil (shear strength, compressibility etc.) & which help in determining its classification accurately are termed as index property:
- For coarse grained soil, Index properties depend upon grain shape & size, relative density etc.
- For fine grained soil, Index properties depend upon Atterberg's limit and consistency.

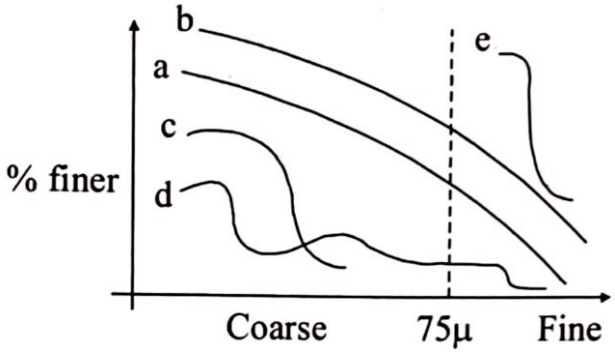
➢ **Sieve Analysis -**

- **Coarse sieve analysis -** It is dry analysis. It is used for gravels. In it, 5 sieves (80, 40, 20, 10, 4.75mm) are used.
- **Fine sieve analysis -** It can be dry or wet analysis.
- It is used for sand (dry analysis). If size is larger than 75 μ, then wet analysis is used (as per IS: 2720 part IV).
- In it, seven sieves (2mm, 1mm, 600 μ, 425 μ, 212 μ, 150 μ & 75 μ) are used.
- According to IS: 1498-1970, The sieves are designated by the size of square opening, in mm or microns.

➢ **Grain Size Distribution Curves**



- D_{60} = Size of the particle such that 60% particle are finer than this size
- D_{10} = Effective size of particles (particles which if present alone will cause the same effect as caused by the soil).
- $D_{60} > D_{30} > D_{10}$



- a → Well graded
- a & b→ Similarly graded
- c→ Poorly/uniformly graded coarse grain soil.
- d→ Gap graded
- e→ Poorly graded fine soil

➢ **Special Points:** If there is a abruptly change in the graph, then it shows the mixture of soil of two different geological formations.

- Boulder > Cobbles > Gravel > Sand > Silt> Clay > Colloidal particle (Size)
- In gap grading, one or more intermediate fractions of particles are absent.
- Coefficient of uniformity $C_u = \frac{D_{60}}{D_{10}}$

(For Gravel, $C_u > 4$ For Sand, $C_u > 6$)

Coefficient of curvature $C_c = \frac{{D_{30}}^2}{D_{60} \times D_{10}}$

(For well graded soil, $1 \leq C_c \leq 3$)

- A uniform soil has less strength & stability than a Non-uniform soil.
- Sedimentation Analysis: Based upon Stoke's Law.

  Stoke' s Law: $V_t = \frac{(\gamma_s - \gamma_w)d^2}{18\mu}$

  V_t = terminal velocity

  d = diameter of the grain
- Stoke's law valid for range of diameter of particle = 0.2 mm to 0.0002 mm
- If particle size is smaller than 0.0002 mm, then Brownian motion will occur & if particle size is greater than 0.2 mm, then turbulent motion will occur.

$$\frac{h}{t} \propto d^2 \rightarrow \frac{d1}{d2} = \sqrt{\frac{h_1}{t_1} \times \frac{t_2}{h_2}}$$

- h = height through which particle falls in t-secs.

➢ **Special Points:**

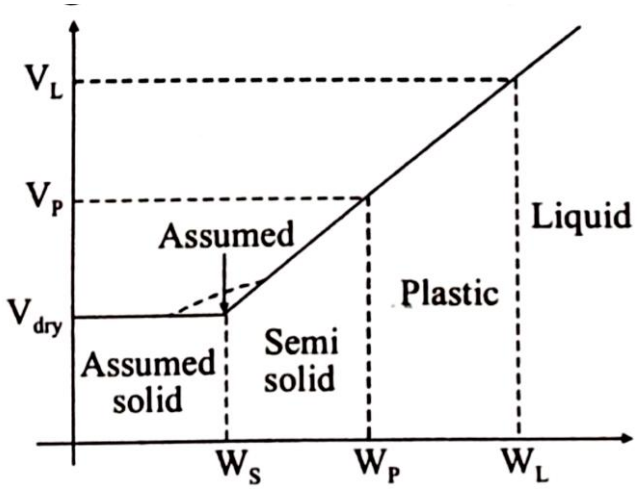
- Pipette method & Hydrometer method, both follow the same principal, but different in taking sample/observations.
- Hydrometer is a device which is used to measure the specific gravity of Liquid.
- 7 gm sodium carbonate + 33 gm Sodium Hexa Meta phosphate + 1 litre water → Dispersing Agent.
- (12-30) gm soil + 1 litre water → Soil solution.

➢ **Corrections in hydrometer Analysis**

- Defloculating (Dispersing) Agent correction → Always negative (C_d)
- Meniscus correction → Always positive (C_m)
- Temperature correction If temp.is more than 27°C, its positive otherwise negative (C_t)
- Combined correction $C = C_m - C_d \pm C_t$

➢ **Consistency limits**

- It is the relative case with which a soil can be deformed. Atterberg classified the consistency in 4-stages solid, semi-solid, plastic, liquid stage



V_{dry} = Volume at shrinkage limit.

V_P = Volume at Plastic limit.

V_L = Volume at liquid limit.

W_L = Water content at liquid limit.

W_P = Water content at plastic limit.

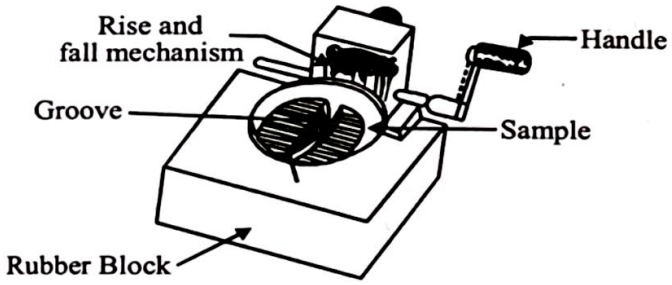
W_s = Water content at Shrinkage limit.

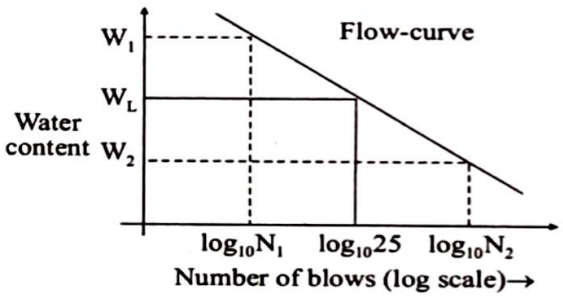
$$\frac{V_L - V_P}{W_L - W_P} = \frac{V_P - V_{dry}}{W_P - W_s}$$

- **Special Points:** Naturally occurring water content in soil is generally between W_L & W_P

- **Liquid limit -**Minimum water content at which soil has tendency to flow.
  - All soil at liquit limit have similar shear strength (Negligible, 2.7kN/m^2)
  - Liquid Limit of soil used in both base & wearing course of highway should not be more than 35%.
  - Found out by two tools → (a) Casagrande's tool (b) Cone penetration.

❖ Casagrande's tool





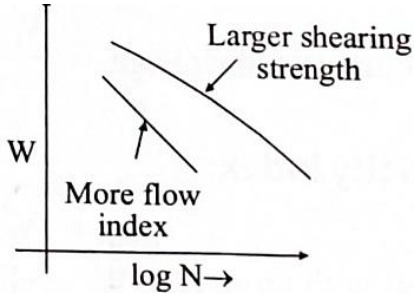
- Soil about 120 gm of an air dried sample passing through 425μ IS sieve is taken in a dish and mixed with distilled water to form a uniform paste.
- Water content at which 25 blows close the groove (width at bottom-2 mm, width at top - 11 mm & 8 mm deep) cut in soil sample placed in Casagrande's bowl is called liquid limit.
- If the Material of base of the casagrande's liquid limit device on which the cup containing soil paste drops (height - 10mm) is softer than standard hard rubber, then liquid limit of soil always increase.

- **Flow Index (I_f):** Slope of flow curve is called flow index

$$I_f = \frac{W_1 - W_2}{(log_{10}N_2 - log_{10}N_1)}$$

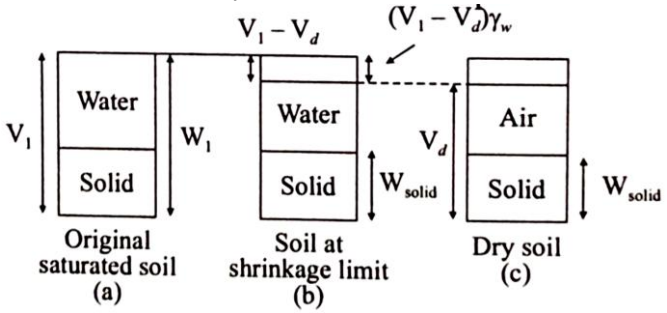
$$I_f = \frac{W_1 - W_2}{\log\frac{N_2}{N_1}}$$

$$\text{Flow Index} \propto \frac{1}{Shear\ Strength}$$



- **Plastic limit**
  - It is minium water content at which soil is in plastic stage.
  - Shear strength at the plastic limit is about 100 times at that liquid limit.
  - At plastic limit, a soil when rolled into a thread of 3 mm, does not show any crack on surface. It starts to crumble.

- **Shrinkage limit**
  - It is minimum water content at which soil is completely saturated or the maximum water content at which further reduction in water content does not cause any descrease in the volume of soil.



Chapter 3 : Classification of Soil

➢ Soil classification is done on the basis of index properties such as grain size distribution & plasticity. These are important systems of classification –

1. **The Unified Soil Classification System (USCS):** It was developed by casagrande (1948) for the use in air field construction. Fine grained soils on the basis of plasticity characteristics but coarse grained soils were classified on the basis of grain size distribution.
   - The soils are classified into four major groups, namely, coarse grained, fine grained, organic soil & peat.

2. **American Association of State Highway and Transportation Official (AASHTO):** Soil are classfied into 8 groups from A1 to A7 with A8 for muck or peat

   Group index: $\boldsymbol{GI = 0.2a + 0.005ac + 0.01bd}$

   Where a = % passing through 75 μ sieve -35 $\quad 1 \leq a \leq 40$

   b = % passing through 75 μ sieve -15 $\quad 1 \leq b \leq 40$

   c = liquid limit -40 $\quad 1 \leq c \leq 20$

   d = plasticity index -10 $\quad 1 \leq d \leq 20$

   - The value of GI lie in the range (0-20)

Type of subgrade soil	Group index range of subgrade
Good	0-1
Fair	2-4
Poor	5-9
Very poor	10-20

   - If the calculated value is negative, it is reported as zero.
   - Group index 0 indicates good subgrade material but group index of 20 indicates very poor subgrade material.

3. **Indian standard soil classification system:** Fine grained soil in indian standard soil classification are sub divided into low, medium, high on the basis of compressibility while in unified soil classification system it has only two categories of low & high compressibility.

❖ Soil classification based upon grain size (mm)

Coarse Grained Soil							Fine Grained soil	
Boulder	Cobbler	Gravel		Sand				
		Coarse	Fine	Coarse	Medium	fine	silt	clay
>300mm	300-80	80-20	20-4.75	4.75-2.0	2-0.425	0.425-0.075	0.075-0.002	<0.002

➢ **Special Points:**
   - Fine sand is a coarse grained soil
   - BIS classified soil into 18 groups

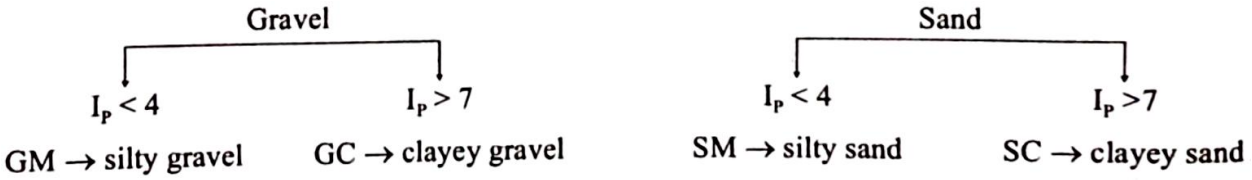
➢ **Coarse grained soil classification**

Case 1: When fines (particles less than 75 μ m) are less than 5%

Case 2: When fines are between 5-12%
   - Dual symbol is used & also called Border line case.
   - Divided into 8 parts based on gradation & fines.
   - **For Ex:**
     SP-SC→Poorly graded sand with clay as fines.

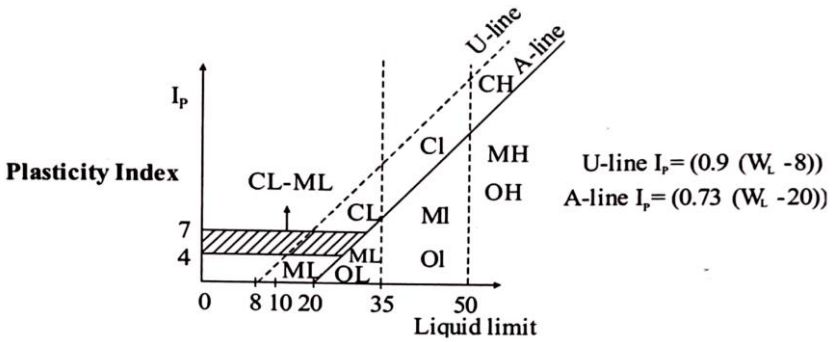
GW-GM→ Well graded gravel with silt as fines

Case 3: When fines are greater than 12%



- **Special Point:** If I_P betwen 4-7, dual symbols will be used.
- **From Dual symbol method -**
  - Gravel -G, Sand - S, Well Graded Soil – W, Silt - M, Clay- C, High Compressibility- H, Low Compressibility- L, Intermediate Compressibility-I, Poor Graded Soil- P, Organic Soil- O, Peat- P_t

- **Fine grained soil classification**



  - Classification of fine Grained soil is done on the basis of plasticity chart.

- **SAND**
  - Sand particle consist of small grain of silica (SiO_2). It is formed from sandstone's decomposition due to various effects of weather.
  - According to natural source of sand, it is classified into following types-

1. **Pit Sand -** It is obtained by forming pit into soil.
   - It consist of sharp angular grain.
   - Excavated from a depth of about 1 - 2 m from the ground level.
   - If it is free from salts, excellent material for mortar or concrete work.
2. **River Sand -** It is obtained from bank or bed of river.
   - Its colour is almost white.
   - It consist of fine rounded grains.
3. **Sea Sand-** It is obtained from sea shores.
   - Its colour is light brown
   - It is consist of fine rounded grains.
   - It contain salts. So, its use is avoided for engineering work

- **Special Point:** Nala is not a good source of good quality sand due to the presence of impurities (specially organic impurity), which may cause detrimental effect on the engineering works.

- **According to size of grain-**
  - **Fine sand:** It is the sand passing through a screen with clear opening of 1.5875 mm. It is mainly used for plastering
  - **Coarse sand:** It is the sand passing through a screen with clear opening of 3.175 mm. It is mainly used for masonry work.
  - **Gravity sand:** It is the sand passing through a screen with clear opening of 7.62 mm. Generally It is used for concrete work.

UNIT : 2 Hydrology

Chapter 1 : Introduction

- Hydrology is the science of occurrence, circulation & distribution of water of the earth and its atmosphere.
- Evaporation from ocean contributes 90% of the atmospheric moisture
- In the ocean, about 9% more water evaporates than that falls back as precipitation.
- Average Annual rainfall over whole India is 119 cm
- Chemical symbol for Ice as per UNESCO is H_2O
- A total of 14% of heat is received by atmosphere from Direct Sunlight but a total of 34% of heat is received by atmosphere from Earth.

- **Conduction:** The Transfer of heat through the molecules of matter in any body
- **Interception:** Short term retention of rainfall by vegetation.
- **Infiltration:** The movement of water into the soil of the earth's surface.
- **Evaporation:** It is the conversion of liquid to the vapour phase
- **Precipitation:** It is the deposition of water on the Earth's surface in the form of rain, snow, hail, frost & so on..
- **Transpiration:** It is the soil moisture taken up through the roots of a plant & discharged into the atmosphere through evaporation. It occurs dur-ing photosynthesis
- **Runoff:** It is the volume of water drained by a river at the outlet of a catchment
- **Percolation:** The movement of water from one soil zone to lower soil zone.
- (Infiltration + Depression storage + Interception) = (Rainfall - Runoff)

- **Hydrological Budget Equation**

Inflow - Outflow = Storage

- It is based upon conservation of mass.
  P-R-G-E-T = ΔS
  Where,
  P = Precipitation, R = Runoff
  E = Evaporation, T = Transpiration
  G =Net Ground water inflow
  ΔS Net increase in storage

$$\textbf{Residence time} = \frac{Volume\ of\ water\ in\ a\ phase}{Average\ flow\ rate\ in\ the\ phase}$$

- Avg. Residence time of ocean is larger than that of global ground water

- **Instruments used in measurement**

1. Relative humidity	Psychrometer
2. Hydraulic conductivity	Permeameter
3. Temperature and Humidity	Thermohygrometer
4. Capillary potential	Tensiometer
5. Wind velocity	Anemometer
6. Rainfall depth	Ombrometer/Pluviometer
7. Evapotranspiration	Lysimeter
8. Evaporation	Atmometer
9. Transpiration	Phytometer
10. Humidity	hytometer
11. Infiltration capacity	Rainfall simulator

- **Isopleth:** A line drawn on map along which the value of a particular phenomenon is uniform.

Name	
1.Isobar	Pressure
2. Isobath	Depth in sea
3. Isohaline	Salinity
4. Isohels	Sunshine duration
5. Isohyets	Rainfall
6. Isopleths	Evapotranspiration
7. Isotherm	Temperature
8. Isonif	Snowfall

- **Special Point:-** Isochrones is a line on map which connect points having equal time of travel of the surface run off to catchment outlet.

Chapter 5 : Runoff & Drought

- Hydrograph: Discharge in a stream plotted against time chronologically.

$$\textbf{Runoff Coefficient} = \frac{Runoff}{Rainfall}$$

- Both direct run off hydrograph & effective rainfall hyetograph represent the same quantity (rainfall excess) but in the different units
- The area of effective rainfall hyetograph Multiplied by the catchment area give the total runoff volume

➢ **Classification of hydrograph -**

(a) Short term hydrograph - Flood hydrograph
(b) Long term hydrograph - Monthly, seasonal and annual hydrograph.

Long term hydrographs are used in calculating surface water potential of stream, Reservoir studies & drought studies.

➢ **Classification of rivers**

(A) Based on location of reach - Mountain rivers, Rivers in flood plains., Delta rivers, Tidal rivers
(B) Classification of alluvial rivers based on stability - Stable meandering rivers, Aggrading rivers, Degrading rivers.
(C) Based on plan-form - Straight rivers, Meandering rivers, Braided river

- Ist June in India is considerd the beginning of the water year.

➢ **Aquiclude:** It is a geological formation, which is highly porous but not permeable due to very small size of pores.
➢ **Example:** Clay
➢ **Aquitard:** It is a formation through which only seepage is possible & therefore, yield is insignificant compared to an aquifer.
➢ **Example:** Sandy Clay
➢ **Aquifer:** It is a saturated formation of earth material which not only stores water but yields, in sufficient quantity easily due to its high permeabil-ity.
➢ **Example:** Deposits of Sand & Gravel.
➢ **Aquifuge:** It is a geological formation which is neither porous nor per-meable.
➢ **Example:** Massive compact rock without any fracture.

List -i	List-ii
Specific yield	Volume of water drained by gravity per unit drained volume of aquifer
Specific retention	Volume of water retained per unit volume of aquifer
Specific storage	Volume of water released from unit volume of aquifer for unit decline in piezometric head

Specific yield + Specific retention = Porosity

- The performance of a well is measured by it's specific capacity, which is the discharge of the well per unit drawdown.

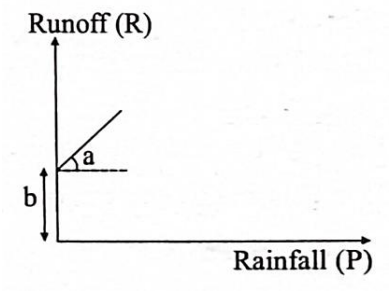
Runoff characteristics of stream		
Perennial	**Intermittent**	**Ephemeral**
Carries flow throughout the yeas	Limited contribution from GW	No base flow contribution Lasting for a very short time

- **Rainfall Runoff Relationship**

  R = aP + b

  a $= \frac{N\,\Sigma\,PR-(\Sigma P)(\Sigma R)}{N\Sigma P^2-(\Sigma p)^2}$

  b $= \frac{\Sigma R-a\Sigma p}{N}$



- **Coefficient of correlation**

r= $\frac{N\,\Sigma PR-(\Sigma p)(\Sigma R)}{\sqrt{(N\Sigma p^2-(\Sigma P)^2(N\,\Sigma\,R^2-(\Sigma R)^2)}}$

- **Khosla's formula** for Monthly Runoff: It is indirectly based on Water- budget equation & developed for small catchment

Runoff =Rainfall – Losses

Losses = 0.48 (mean monthly Temp(T_m))

Index of Wetness = $\frac{Rainfall\ in\ a\ year}{Average\ Annual\ rainfall}$ **x 100**

% Rain deficiency 100% Index of wetness

- River forecast is short range forecast & it is most reliable but this gives an advance warning of 12-40 hr. only.
- Hydrological forecast is medium range forecast. In this rainfall-runoff relationships are used to predict flood levels with a warning of 2-5 days.
- Meteorological forecast is long range forecast & it is least reliable but this gives maximum time for advance notice.
- The drainage density is the average length of the streams per unit drainage area within the basin.

- **Droughts (deficiency in precipitation)**
  - **As per Indian meteorological department**

Decrease from normal Precipitation	Classification
< 25%	No drought
26-50 %	Moderate
>50%	Severe

- **Agriculture Drought-** It occurs when the soil moisture & rainfall are inadequate during the growing season. There will be extreme crop stress & wilt conditions.

  Aridity Index = $\frac{PET-AET}{PET}$ X 100

  Where, AET Actual Evapotranspiration

  PET = Potential Evapotranspiration

AI Anomaly	Classification
0 (or – ve)	Non arid
1 -25	Mild
26- 50	Moderate
>50	Severe

- **Special Point:** A year in India is considered to be drought year if area affected by moderate/severe drought is more than 20% of total area of country.

Chapter 7 : Floods & Flood Routing

(a) Standard Project flood (SPF): Flood from most severe combination of the meteorological & hydrological conditions excluding extremely rare combination.

(b) Maximum Probable flood (MPF): It includes the extremely rares catastrophic floods & is usually confined to spillway design of very high dams. The SPF is generally around 80% of the MPF for the basin.

(c) Maximum flood: Correspond to peak flow obtained from Observed data.

(d) Design flood: It is adopted for design of Hydraulic structure like spillways, flood banks, bridge openings etc. It is the maximum flood that any structure can sefely pass.

- **Probable maximum Precipitation (PMP):** Greatest or extreme rainfall of a given duration that is physical possible over a station.
- **Selecting Design Flood:** Central Water Commission

Spillway for projects with Storage > 60 M m³	
Pick up wiers	**PMP & MPF**
Aqueducts	**Return period of 100 or 50 years**
(a) Waterways	**T= 50 years**
(b) Foundation free board	**T = 100 years**
Permanent barrage & minor dams with storage < 60 M m³	**SPF**

- **Special Points:** Gumbel's method is used for estimation of design flood for a particular return period.

Khosla's theory is used for design of weir & barrages on permeable foundation.

The design period usually adopted for dam is 25-100 years, wells 5 years, distribution system 35 to 45 years.

- **Empirical Formula's for flood peak**

(a) *Dicken Formula used in Central & northern parts of the country.*

$$Q_P = C_D A^{\frac{3}{4}} \quad , \qquad Q_P \rightarrow m^3/sec \text{ , } C_D \rightarrow 6 \text{ to } 30 \text{ , A} \rightarrow km^2$$

(b) Inglis Formula used in western Ghats of Maharashtra

$$Q_P = \frac{124\,A}{\sqrt{A+10.4}}$$

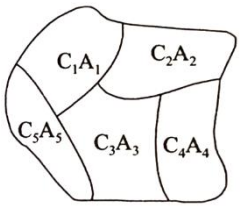
(c) Ryves formula used in Tamilnadu , part of Andhra Pradesh & Karnataka

$$Q_P = C_r A^{2/3} \quad , \qquad C_R \rightarrow \text{Ryves Coefficient}$$

- **Rational method**

$$Q_P = \text{C i A}$$

Where C = Runoff Coefficient $= \frac{Runoff}{Rainfall}$



$$C_{eq} = \frac{C_1A_1 + C_2A_2 + \cdots + C_nA_n}{A_1 + A_2 + \cdots + A_n}$$

i = Intensity of Rainfall, depends on time of concetration (t) & Return period of rainfall.

- **Time of Concentration (kirpich Equation)**

  t_c= 0.01947 $L^{0.77}$ $S^{-0.385}$

  S= Slope of Catchment

  L = Maximum length of Travel by Water

- **Special Point:** Rational formula is found to be suitable for peak flow prediction in small catchment upto 50 km² in area.

- **Estimation of Design flood for a particular return period: Gumbel's method**
  - It is based on extrapolation for large return period

  $X_r = \bar{x} + K\sigma_{n-1}$

  $\sigma_{n-1} = \sqrt{\frac{\Sigma(X-\bar{X})^2}{n-1}}$

  X_r= Value of variate of return period T

  $\bar{x} = \frac{\Sigma x}{n}$

  n = Number of years of record

  K = Frequency factor

  K = $\frac{y_T - \bar{y}_n}{S_n}$

  y_T = Reduced variate $y_{T=} - \ln in \left(\frac{T}{T-1}\right)$

  S_n = standard deviation reduced variate

  $\bar{y}_n$ = Mean of reduced variate

  For n > 50 y_n= 0.577 $S_n = 1.2825$

- **Confidence Limit**

$$\boldsymbol{X_{1/2} = X_t \pm f(\alpha)S_e}$$

$f(\alpha)$ = function of confidence probability 'α'

α in %	50	68	80	90	95	99
$f(\alpha)$	0.674	1.0	1.282	1.645	1.96	2.8

S_e = probable error = $\frac{b\sigma_{n-1}}{\sqrt{n}}$

k = frequency factor , b = $\sqrt{1 + 1.3k + 1.1k^2}$

- **Risk- Reliabilly**
  - Return period refers to the inverse of the probability of exceedance of an event.
  - Probability of exceedance is P, Return period T = $\frac{1}{p}$
  - Probability of Non-occurrence q = 1− p
  - Risk → Probability of exceedance atleast once = 1 -q^n.
  - Assurance/Reliability → Probability of Non-occurrence =q^n.
  - Probability of exceedance of m times in n years = $n_{c_m p^m q^{n-m}}$
  - Probability of exceedance or exactly one time in n years = $n_{c_1 pq^{n-1}}$

UNIT : 7 Reinforced Cement Concrete (RCC)

Chapter 1 : Basic of R.C.C

- Francois Caignet was a French industrialist and the first to use t reinforced concrete.

- **Plain concrete** is a mixture of sand, gravel, cement & water resulting into solid mass.
- **Reinforced concrete** is Concrete with reinforcement embedded in Bond between steel & surrounding concrete ensures strain compatibility (large deflection). Reinforcing steel give ductility to concrete.
- **Special Point**: Steel is used along with concrete because thermal expansion coefficient of both steel & concrete is reasonable equal. Hence with increase in temperature of steel & concrete will expand in same magnitude & thermal cracks will not occur.
- **Grade of concrete:** Compressive strength measured by standard test on concrete cube (150 mm size) tested 28 days after casting & continuo curing.

(Important fact)	
Volume of Concrete	**NO. of Sample**
1-5	1
6-15	2
16-30	3
31-50	4
>50	(4+1) No. for each $50m^2$

- Strength of cube is the average of 3 specimens of a sample, when individual variation should not be more than + 15% of average. If variation is more, test result of the sample is rejected.
- Cube is always tested on sides.

1. Mean Straight $f_m = \frac{\Sigma(Strength\ of\ sample, f)}{No.of\ sample, m}$
2. Standard deviation $\sigma = \sqrt{\frac{\sum(f-f_m)^2}{m-1}}$

Assumed Standard Deviation	
Grade of concrete	**σ (N/mm²)**
M10 M15	3.5
M20 M25	4
M30 M35 M40, M45 M50 M55, M60	5

- **Characteristic strength (f_{CK}):** Strength below which not more than 5% of test result are expected to fall.

$$f_{ck} = f_m - 1.65\sigma$$

- **As per IS 456 : 2000 Cl 38.1 (C**): For the design of flexural members the characteristic strength of concrete is taken as 0.67 f_{CK}

- Larger size leads to more variability in strength. Hence, the strength of concrete cylinder will be lesser than the cube strength.

➢ **Grade's of concrete**

- High strength concrete = 8 No (M65, M70, M75, M80, M85, M90, M95, M100)
- Standard grade of concrete = 8 No. (M25, M30, M35, M40, M45, M50, M55, M60)
- Ordinary grade of concrete = 3 No. (M10, M15, M20)

➢ **Design Methods:** (a) Nominal mix (upto M20 grade only) (b) Design mix (IS 10262:1982)

➢ **Concrete Mix Design:** It is economical selection of relative proportions of various ingredients of concrete such that it remains workable in fresh state & impermeable and durable in harden state.

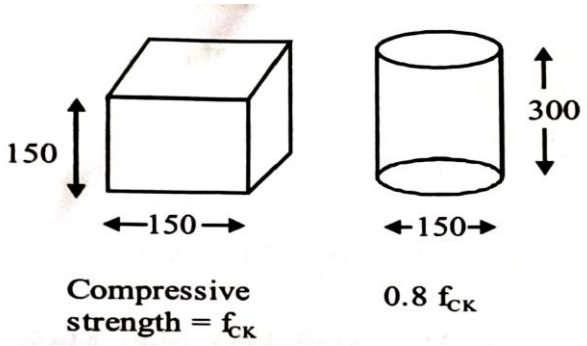
- In Nominal Mix Design Method, Specified in terms of total mass of aggregate, and volume of water to be used per 50 kg of cement.

Cement : FA : CA	
M5	1 :5 : 10
M7.5	1 :4 : 8
M10	1 :3 : 6
M15	1 :2 : 4
M20	1 :1.5 : 3

➢ **Steps involved in Design Mix Process are**

(a) Target mean strength $f = f + 1.65\ \sigma$
(b) W/C from charts.
(c) Water content based on workable ratio of fine & coarse aggregate, y mass based on type & grading of aggregate.
(d) Find cement content from (b) and (c) above
(e) Mass of FA & CA from absolute volume principle.
(f) Weight of ingredient per batch ban on capacity mixer.

➢ **Compressive strength of concrete in structures:**



- For size more than 450 mm there is no decrease in compressive strength
- Hence consider as 0.67 f_{ck}
- Cube Strength = 1.25 Cylinder strength

➢ **Tensile strength of concrete**

- Since concrete does not take any tensile strength, it is taken as zero While, IS code recommends the flexural tensile strength to be calculated using

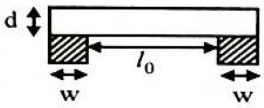
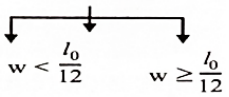
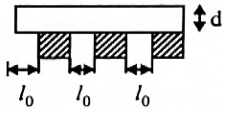
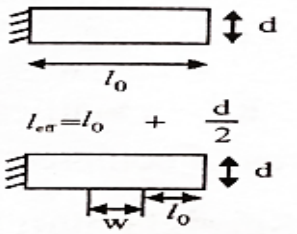
$$\mathbf{f = 0.7f\sqrt{f_{ck}}}$$

- The tensile strength of concrete can be expressed as follows:

(a) Flexural tensile strength.
(b) Splitting tensile strength.
(c) Direct tensile strength.

Chapter 3 : Codal Provisions for Beam and Slab

❖ **Effective Spen (L_{eff})**

Effective span (l_{eff})		
	Continuous beam or slab	**Cantilever**
Simply supported beam or slab  min. of $\begin{cases} l_0 + d \\ or \\ l_0 + \frac{w}{2} + \frac{w}{2} \end{cases}$	Continuous beam or slab  same as simply supported case  Minimum of $\begin{cases} l_0 + \frac{d}{2} \\ or \\ l_0 + \frac{w}{2} \end{cases}$	 $l_{eff} = l_0 + \frac{w}{2}$

➢ **Special Points:**

- In case of spans with roller or rocket bearings, the effective span shall always be the distance between the centres of bearings.
- For frames, effective span is it's centre distance between members.

➢ **Check for Deflection**

➢ **As per Clause 23.2 of IS 456,** stipulates the limiting deflections under two heads as given below:

(a) The maximum final deflection should not more than span/250 due to all loads including the effects of temperature, creep & shrinkage & measured from the cast level of the supports of floors, roof & all other horizontal members.

(b) The maximum deflection should not more than the lesser of span/350 or 20 mm including the effects of temperature, creep & shrinkage occurring after erection of partitions & the application of finishes.

➢ **Control of Deflection**

$$\frac{\textbf{span}}{\textbf{depth}} < \left(\frac{\textbf{l}}{\textbf{d}}\right)_{\textbf{basic}} \times \frac{\textbf{10}}{\textbf{spen}} \times \mathbf{K_1} \times \mathbf{K_c} \times \mathbf{K_f}$$

- Where, K_t = modification factor for tension reinforcement depending area & stress of steel for tension reinforcement.

➢ **Special Point:** This factor allows the designer to make shallow members by increasing area of tension reinforcement.

- K_f = modification factor for flanged beams depends on ratio of weh width to flange width.

➢ **Special Point :** Here K_t and K_c should be calculated based on area $b_f d$

- K_c = modification factor for compression reinforcement depending on area of compression reinforcement

➢ **Special Point:** It's always greater than 1, as compression reinforcement the stiffness of the beam.

(1) If span $\leq$ 10m, then $(\frac{l}{d})_{basic}$ values are

Cantilever beam	7
Simply supported beam	20
Continuous beam	26

Type of slab	Type of reinforcement	
	Mild steel	Fe 415
Simply supported	35	28
Continuous	40	32

Where as ($\frac{10}{span}$) factor is neglected.

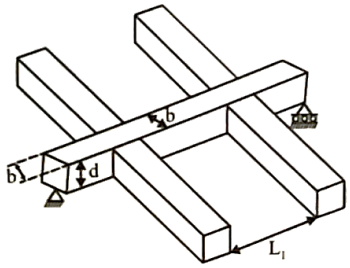
(2) If span > 10 m, then ($\frac{10}{span}$) factor is also multiplied (But if cantilever beam > 10 m, then deflection calculations should be made)

- **Slenderness Limits to Ensure Lateral Stability**

According to the IS code **456:2000 clause 23.3:**

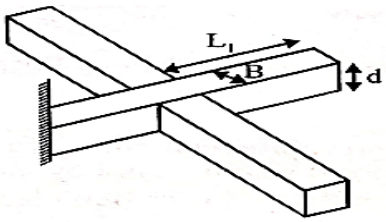
1. **For simple supported or continuous beam**

$$\left.\begin{matrix} L_1 \not> 60b \\ \not> 250\ \frac{b^2}{d} \end{matrix}\right\} \text{Whichever is less}$$



1. **For a cantilever beam**

$$\left.\begin{matrix} L_1 \not> 25b \\ \not> \frac{100b^2}{d} \end{matrix}\right\} \text{Whichever is less}$$



- **Steel Reinforcement in Beam**

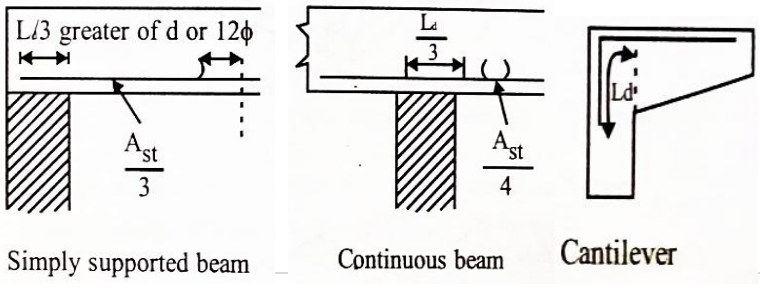
Tension reinforcement

$$\frac{A_{St,min}}{bd} = \frac{0.85}{f_y} \qquad A_{St,min} = 0.04\ bD$$

- **Side face reinforcement**
- **As per IS 456: 2000,**

Side reinforcement is provided 0.1% of web area equally distributed on both face.
Maximum spacing of side face reinforcement is 300 mm or width of beam (whichever less).
Side face reinforcement is provided when

(a) Depth of beam is more than 750mm (When beam is not subjected to torsion)
(b) Depth of beam is more than 450 mm (When beam is subjected to torsion)



- For -ve moment tension reinforcement, atleast 1/3rd of total reinforcement should be provided at all support shall beyond the point of inflection for a distance of not less than "d" or "12ϕ ", (1/16) of clear span whichever is larger.

➢ **Cover:** To protect against corrosion

Environmental Condition	Minimum grade of conc.	No min al cover
Mild	M20	20MM
Moderate	M25	30MM
Severe	M30	45MM
Very severe	M35	50MM
Extreme	M40	55MM

➢ **Arrangement of loads in Continuous beams**

(a) For maximum span moment: Dead load on all spans but live loads on alternate spans.

(b) For maximum moment: Dead load on all spans but live loads on two adjacent spans.

Type Of load	At end Support	At support next to the end support		At all other interior supports
		Outer side	Inner side	
1	2	3	4	5
Dead load and imposed load	0.4	0.6	0.55	0.5
Imposed load (not fixed)	0.45	0.6	0.6	0.6

❖ **Shear Coefficient**

Type of load	Span moment		Support moment	
	Near middle of end Span	At middle of interior span	At Support next to the end Support	At other Interior supports
(1)	**(2)**	**(3)**	**(4)**	**(5)**
Dead load and imposed load	$+\frac{1}{12}$	$+\frac{1}{16}$	$-\frac{1}{10}$	$-\frac{1}{12}$
Imposed load (not fixed)	$+\frac{1}{10}$	$+\frac{1}{12}$	$-\frac{1}{9}$	$-\frac{1}{9}$

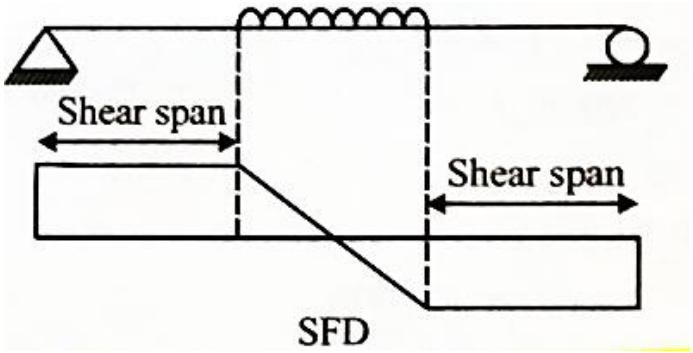
❖ **Moment Coefficients**

➢ **Special Points**: If the span of two sides of support are different or the loading are different, then support moment will be calculated from both sides and average will be taken.

- Mild steel (Fe 250) is more ductile. So, preferred for earthquake zones or where there are possibilities of blast, vibration, impact etc.
- Diameter of reinforcement bars generally available are 4, 5, 6, 8, 10, 12, 16, 18, 20, 25, 28, 32, 36, 40 mm.
- **Slabs:** Plate elements having depth much smaller than it's other two dimensions.
- They carry distributed load primarily by bending

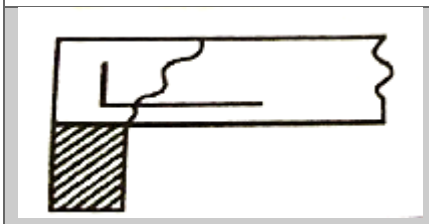
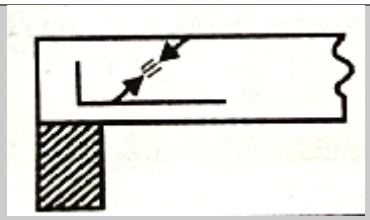
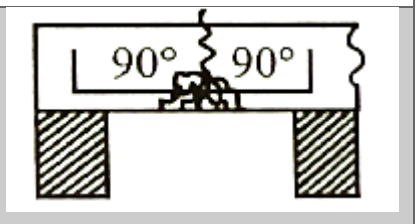
Chapter 4 : SHEAR

- **Shear span:** Shear span is defined as span where shear Force Constant
- **Note: - Contraflexture Point :** It is the Point on beam where bending Moment change its sigh.

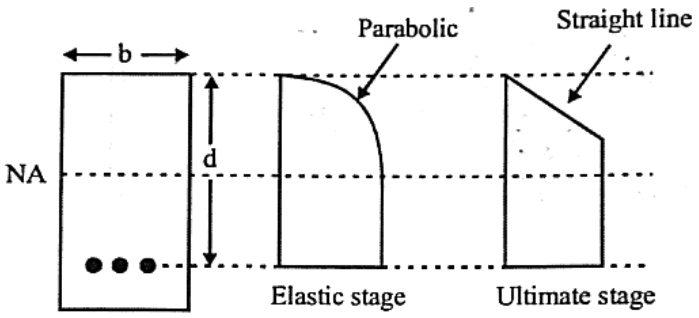


Types to shear		
Flexure	**Torsion**	**Punching**
Shear associated with change in bending moment along the span $\frac{dM}{dX} = V$	Shear associated with a member subjected to torsion	Shear associated with possibility of punching a thin member by point load Ex. Flat slab

- **Modes of Failure Due to Shear**

Modes of failure due to shear		
Diagonal tension failure	**Diagonal compression failure**	**Flexure shear failure**
Due to large shear force & less bending moment. Occur at 45° to horizontal	Due to crushing of concrete when beams are heavily reinforced against shear	Due to less shear force & large, bending moment. Occur at 90° to the horizontal
		

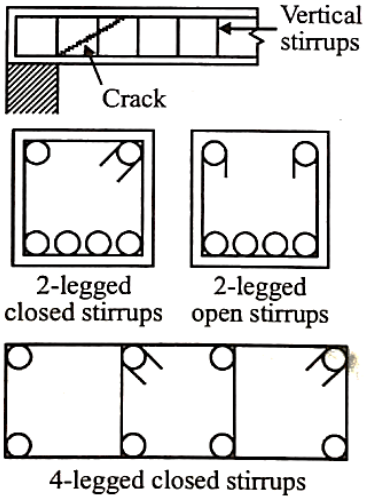
- **Shear Stress distribution**



- **Nominal Shear Strength (τ_u) $= \frac{V_u}{bd}$**
- **Shear reinforcement can be provided in the form of:**
  (a) Vertical stirrups
  (b) Inclined stirrups
  (c) Bent up bars with vertical stirrups

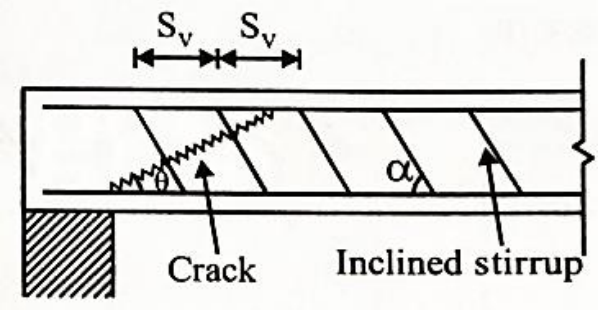
(a) Vertical stirrups: These are best for load reversal case.

- It is the most effective in enhancing the shear resistance of beam.



- Closed strirrups are better since it resists torsion & also helps in confining the compression reinforcement in doubly reinforced section and also reduces the chances of buckling of compression reinforcement**.**

(b) Inclined stirrups: It is ineffective in load reversal.

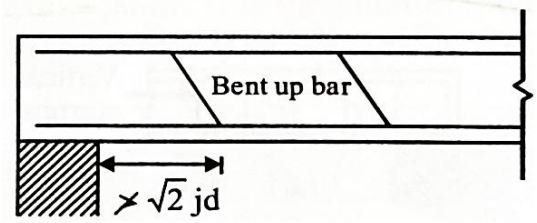


where a = Inclination of stirups

0 = Angle of propagation of Cracks

- It is the most effective reinforcement in reducing width of inclined cracks.
- It can be provided in member having axial tension, resulting in full depth of inclined crack.
- **Note:** $\alpha \not< 45°$, because for a < 45°, there is a possibility of inclined stirrups slipping along the longitudual bars.

(c) Bent up bars



- These are the main tensile reinforcement bend at appropriate location & It is always provided in combination with vertical stirrups.
- They do not enhance the dowel action.
- When bent up bars are provided, their shear resistance contribution should not be more than 50% of the total shear to be resisted through shear reinforcement.

➢ **Special points:** $\tau_{c\,max} \approx 0.63\sqrt{f_{ck}}$, $\tau_{c\,max} > \tau$

τ_c depends on both and f_{ck} *and* A_{st}

Maximum shear stress with shear reinforcement ($\tau_{c\,max}$)

UNIT : 16 Railway

Chapter 1 : Basic of Railway & Rail Joints

- George Stephenson (father of railway) of England succeeded in running the first train on 27th September 1825 between Stockton and Darlington with steam engine.
- In the world India Railways are next only to Russian Railways under a single management.
- Tejas train is first Private train of India (2019).
- First train (fourteen coaches and one steam engine) were run in India on 16th April 1853 between Boribunder (Mumbai) and Thane.

➢ **Rail:** These act as a continuous girders carrying axle loads made up of high carbon steel which convert moving wheel loads of train into point load, which then acts on sleepers.

Requirement of Rails:

(a) Rails are tested by falling weight test/tup test.
(b) Maximum wear of head allowed is 10 mm
(c) Rails are manufactured by open hearth or duplex process.
(d) Minimum tensile strength needed 72 kg/mm^2.

Properties	Flat Footed Ralls	Bull Headed Rails or Double Headed rails
1. Laying and Relaying	Fitting is simpler. So, these can be easily laid or relied.	Laying or relaying is difficult.
2. Strength and Stiffness	These have more strength & stiffness for same weight.	These have lesser stiffness & strength for same weight.
3. Initial cost	Fastenings are lesser and cheaper. So initial cost is less.	Fastening is more and costly. So initial cost is high.
4. Maintenance cost	It has less maintenance cost.	It requires heavy maintenance cost.

➢ **Special Points:**

1. Double Headed rails were used in the beginning.
2. Flat footed rails also known as Vignole's rails and these rails are designed by weight of rail per unit length. These are most commonly used in India.
3. 52 kg rail (52 kg/m F.F) is suitable up to 130 kmph & 60 kg rail is suitable up to speed of 160 kmph.

Length of Rail: Rails of larger length are always preferred because they will have less no. of joints. Rail length of 12.8m for BG tracks & rail length of 11.89 m for MG track are used in Indian railways.

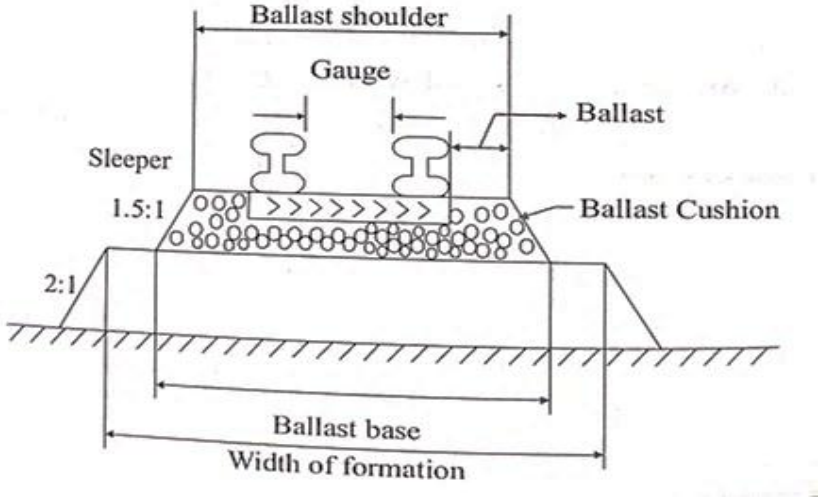
➢ **Special Point:**

$$\frac{wt.of\ Rail}{Wt.of\ Iocomotive} \approx \frac{1}{510}$$

- When wear of head exceeds 5% of total weight, then rail must be replaced.

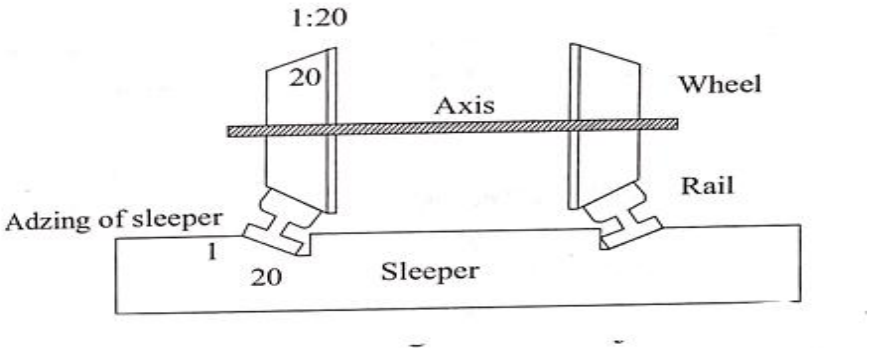
➢ **Permanent way (Railway Track)**

- The combination of rails, fitted on sleepers and resting on ballast & subgrade is called railway track or permanent way.
- It is semi-elastic in nature due to packing of ballast cushion.



Major Defects of Rail			
Corrugated/Roaring Rails	Kinks in rail	Hogged rail	Buckling of rail
Minute depression on the Surface of rails Created where brakes applied or train start	(occur due to loose packing of joints and uneven wear)	Created due to impact action of wheel at the end of rail, head get bend.	Occur due to temperature (specially summer) when there are insufficient gap b/w two end joints.

- **Gauges in Railway Track:** It's the clear distance between inner faces/running faces of two track rails.
  Broad Gauge 1.676m
  Narrow Gauge = 0.762m
  Meter Gauge = 1.0 m
  Light gauge (Feather track) = 0.610 m
  Standard gauge = 1.435m (Delhi metro) (In generally UK and USA)
- **Coning of wheels:** Wheels of the train are made at a slope of 1:20. Which is known as conning of wheels. It reduces the wear & tear of wheel flanges & also prevent the wheels from slipping.
- **Adzing of sleepers:** Also called tilting of rails. For effective use of coning of wheels, the rails are also laid at the slope of 1 in 20 on the sleepers.



- **Rail Joints:** Are needed to hold together the adjoining ends of the rail. They are the weakest part of the track. Its strength is 50% of strength of rail.

Types of Rail joints					
Supported	**Suspended**	**Bridge**	**Compromise**	**Expansion**	**Welded**
Rail ends rests on a single sleeper, called joint sleeper	Rail ends are projected beyond sleepers, called shoulder sleeper	Projected rail ends are connected by a flat or corrugated plate	Two different rail sections are joined by fish plates.	Gap is provided for thermal expansion	Most perfect & strongest type of Joints.

- **Welded Rails:** Rails are welded to provide sufficient restrain at the ends of rail & better degree of fixity of rail to the sleeper.

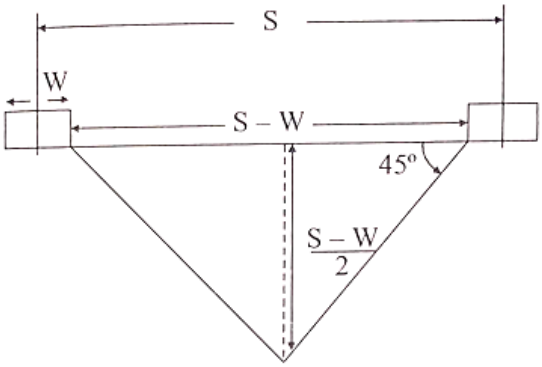
Special Point: Breathing length: minimum length of rail required to be welded at the end of track, so the portion of rail between welded rail does not undergo any thermal expansion or contraction.

Chapter 3 : Ballast and Track Alignment

- **Ballast:** It is high Quality crushed stone with desired specifications placed immediately beneath the sleepers
- **Function of Ballast**
  1. It held the sleepers in position & prevent longitudinal and Lateral movements due to dynamic loads.
  2. It gives some elasticity to track and provides good drainage.
  3. Good Ballast should absorb minimum water.
- **Special Points:**
  - Size of Ballast varies from (1.9-5.1) cm. For wooden sleeper (5.1cm), Steel sleeper (3.8cm) & at switches & crossings (2.54cm).
  - Quantity of Ballast is more on curves with super elevation.
  - In India, this width is kept in between 38 to 43 cm from end of sleepers.
  - The ballast above packing which surrounds the sleeper, is loosely filled called Boxing.
  - The process of ramming the ballast under the sleeper is called packing.
  - The loose ballast between the two adjacent sleepers is known as Ballast crib.
- **Types of ballast**
  (a) **Broken stone:** Best material as ballast, has maximum stability. Igneous Rock such as Granite, Quartzite make good ballast material.
  (b) **Sand:** It provides good drainage & silent track.
  (c) **Gravel or River pebble or shingle:** They are smooth & round, so poor packing and interlocking. Gravel ballast gives better performance in soft formation.
  (d) **Ashes or Cinder:** They have excellent drainage property, Excellent ballast material for station yards & but it is corrosive in nature.
  (e) **Brick ballast:** It is fairly good for drainage.
- **Depth of ballast-Section**
  - Minimum depth of Ballast layer = D_{min}

$$\boldsymbol{D_{min} = \frac{S - W}{2}}$$

  - Where S - Sleeper spacing, W - Width of sleeper, D - Depth of ballast.



- **Width of ballast:** On straight track, it is sleepers' length + 2 × 300 mm at top which work out to be 3.35 m for BG, 2.25m for MG & 1.83m for NG.
  - The side slope is 1.5 horizontal to 1 vertical.

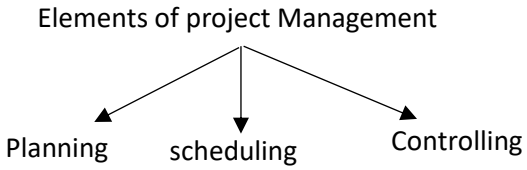
- **Survey works for alignment of track.**
  (a) Traffic survey
  (b) Reconnaissance survey
  (c) Preliminary survey
  (d) Detailed or location survey

UNIT : 22 CPM & PERT

Chapter 1 : Project Management

❖ **Objectives of Project**

(a) To complete project in minimum time period
(b) Completion of project with minimum Cost & without delay
(c) Use of available manpower & local resources as we can



- The concept of functional organization was suggested by F. W. Taylor who recommended the Appointment of specialists at Important positions.

Term	Explanation
Co-ordination	One of the functions of Management.
Unity of Command	One of the principles of organization
Line Organization	Used widely for Civil Engineering Construction
Site Order Book	Used for recording instructions given by the Executive Engineer on site.

1. Project planning:

- Planning means defining the objectives of the project.

Project Planning	Tools for planning
Setting goals	Time & cost estimates
Defining the project	Budgets
Tying needs into timed project Activities	Cash flow charts
Organizing the term	Material availability details Engineering diagrams

2. Project Scheduling

- Scheduling is deciding the order of the activities & allocation of Resources to the activities

Project Scheduling	Tools for Scheduling
Assigning resources	CPM & PERT
Relating activities to each other	Milestone charts
Updating & revising timely	Cash flow schedules Gantt chart

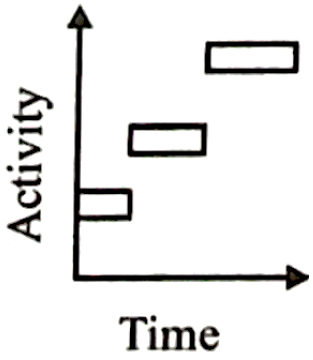
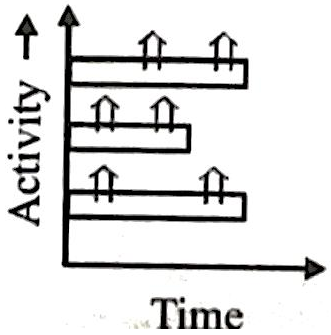
3. Project controlling

- Controlling involves execution of planning & scheduling.

Project Controlling	Tools for controlling
Monitoring resources, cost	PERT chart
Revising & changing plans Shifting resources to meet time, Cost & quality demands	Reports describing Slack activities, delayed activities Quality of work completed etc.

➢ **Special Point:** Planning & scheduling are done before the start of a project where as controlling after.

❖ Methods of Project Management

Method of Project management			
Bar charts	**Milestone charts**	**Network Analysis**	
		Activity on node (AON)	Activity on Arrow (AON)

1. Bar charts: Also called Gantt chart. Introduced by Henry Gantt in 1917 AD

- It is a graphical representation of activity vs time.

➢ **Advantages:**

(a) Resource requirement can be depicted
(b) Progress expressed as percentage
(c) Simple to draw & No special skill required.
(d) Visual representation of the project

➢ **Limitations**

(a) Lack of degree of details
(b) Cannot be used for the project where there is uncertainity in the time determination
(c) Critical activities not shown
(d) Activity inter-relationship not shown
(e) Review of project progress
(e) Review of project progress

2. Milestone charts: For each activity, there are certain key events which mark the competition of certain portion of the main activity such key events are called milestone. By milestone charts, the relationship between two specific milestones on an activity is revealed but interdependency among milestones between different activities is not indicated.

3. Network analysis: It is a graphical model or plan which lists out the sequence of various activities (with interdependencies) which are required for completion of a project.

➢ **Special Point:** Bar chart is activity oriented but milestones chart is event oriented.

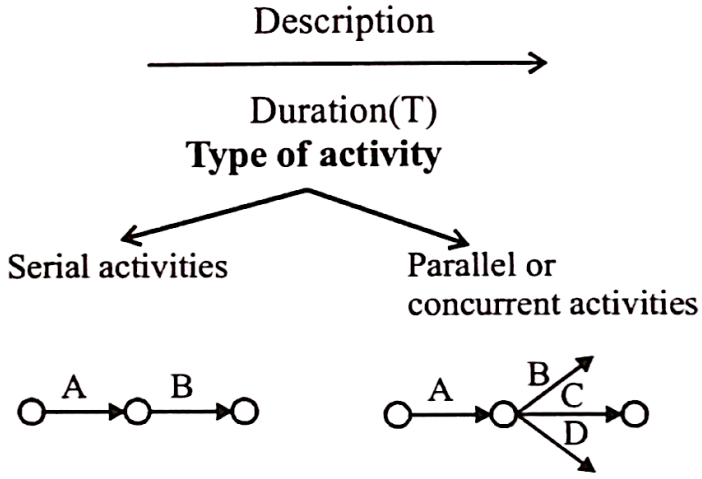
- Correct sequence of Analyzing a project will be as follows:

(i) Work Breakdown structure.
(ii) Network Diagram.
(iii) Resource Allocation & Scheduling.
(iv) Project Completion time
(v) Time cost study.

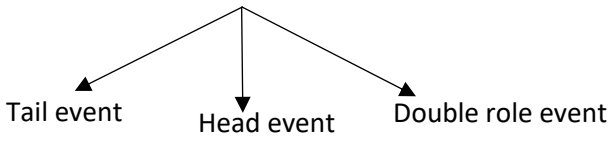
Chapter 2 : Network Technique

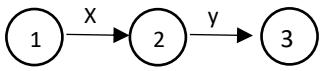
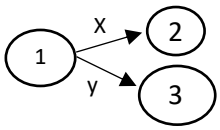
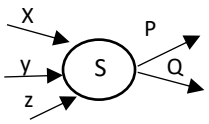
- Network is a flow diagram consisting of activities & events connected logically & sequentially.

➢ **Activity:** A project can be broken into various jobs in the form of operations & each operation consuming time or resource is called an activity.

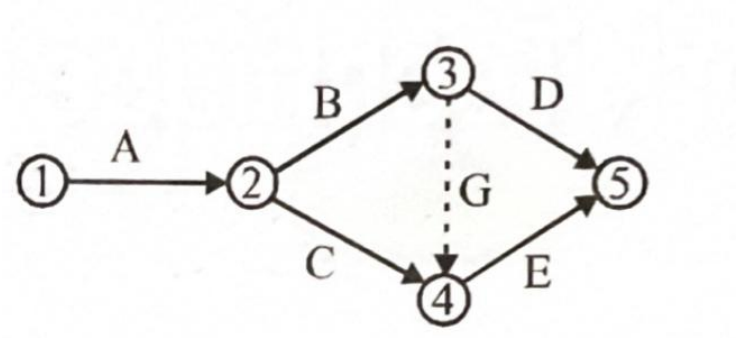


➢ **Event:** It is an instant of time at which some specific milestone has been achieved. It denotes the start or completion of an activity, & it is represented by nodes of different shapes like rectangular, circular, square or oval. An event does not consume any time or resource.



		
1.Is tail event for activity X 2.is tail even for activity Y (Belonging of an activity)	**2.is the head event for x 3. is the head event for Y (end of an activity)**	**S acts a tail event for some activities (P,Q) & head event for some activities (X , Y , Z)**

➢ **Dummy Activity:** It is an artificial activity represented by dashed arrows which neither consumes any time nor resources.



- Activity G is dummy activity. Dummies maintain the logic of network diagram & keeps the numbering system of the network unique.

❖ **Rules for providing dummies:**

(A) If dummy is the only activity coming out from a node & terminating into some node. Then, dummy can be removed & the two nodes at the two ends of dummy can be merged into one.

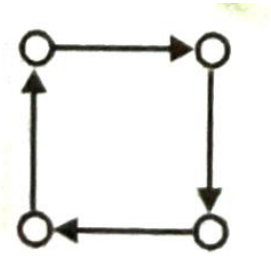
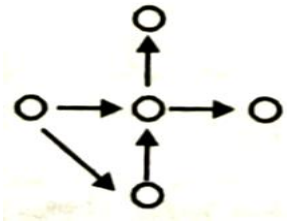
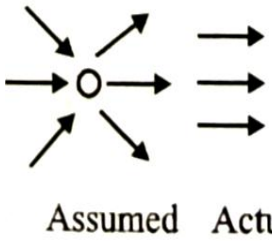
(B) If two or more activities having same set of successors & succeeding activities are having other predecessors as well, then two activities should terminate into one single node.

(C) If two or more activities, emanating from different nodes & having same set of preceding activities, then the two activities should emanate from a single node.

(D) If dummy is the activity terminating into a node, then dummy can be removed & the nodes at the two ends of the dummy can be merged into one.

(E) Dummy activities which shows predecessor relations already implied by other activities are called as Redundant dummies & can be removed.

➢ **Special Point:** System of numbering of events in a network diagram in order to maintain the logical sequence is given by FULKERSON'S Rule.

Error in network diagram		
Cyclic /Looping error	**Dangling error**	**Wagon wheel error (Most difficult error)**
		

UNIT : 24 Auto-CAD

- Auto-Cad is a Commercial Computer -aided design (Cad) and drafting software application.
- Auto Cad - Automatic Computer Aided Design
- CADD - Computer Aided Design and Drafting
- CAD - Computer Aided Design
- Auto CAD was first developed by Autodesk in December 1982 and Latest Version Auto Cad - 2022 version 24.1 released on 23 March 2021.
- Father of Auto Cad - **Mike Riddle**
- Founder of Autocad - **John Walker**
- Operating system - Windows, Macos, ios, Android

❖ Type of Autocad

1. 2D CAD (Flat Drawing)
2. 2.5D CAD (Prismatic model)
3. 3D CAD (3D objects)
4. 3D Wireframe & surface modelling
5. Solid Modelling (Solid Geometry)

- Auto Cad file format - .dwg
- Auto Cad backup file format - .BAK
- Auto Cad Auto save file format - .SV$

➢ **Note: -** The Character limit for file is 256 Character.

❖ Type of unit in Auto CAD -

1. Architectural
2. Decimals
3. Engineering
4. Fractional
5. Scientific

❖ Process of Designing - 6 Steps

1. Recognition of need
2. The definition of a problem
3. Synthesis
4. Analysis & optimization
5. Evaluation
6. Presentation

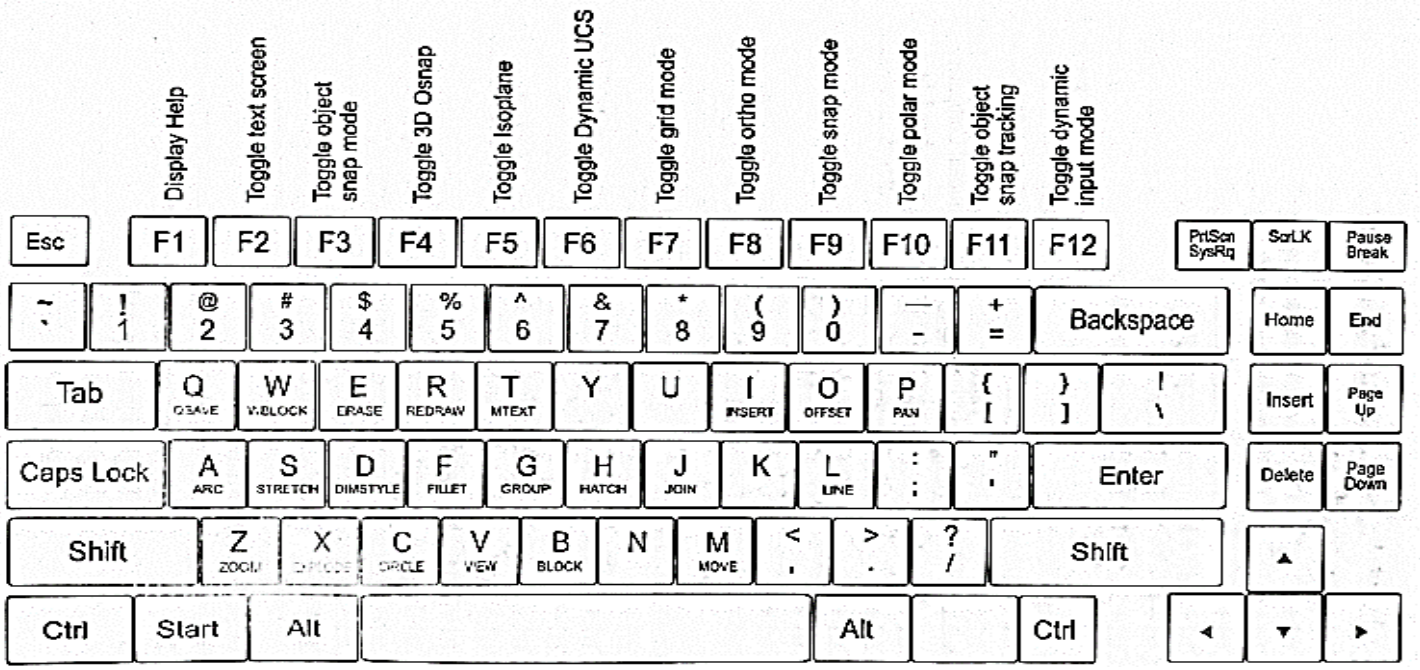
❖ Functionality area of Auto Cad - 4 Categories

1. Geometric Modelling
2. Engineering Analysis
3. Design review & Evaluation
4. Automated Drafting

❖ Work Space - 3 work spaces available

1. Drafting & annotation
2. 3D Basics
3. 3D Modelling

- **CRT -** Cathode Ray Tube Technology used in Traditional Computer monitors & TV. The colour you see on screen is produced by a blend of red, blue and green light. Computer communicate with user by CRT.
  - .dwt - Drawing Template Extension
  - .dwf - Design web format extension
  - acad.dwt - Autocad Default Template
  - Polar co-ordinates are used mostly for drawing angled lines.
  - Polar array creates new objects in a circular pattern.
  - Isometric drawing - A 2D pictorial view of object.
  - Status bar contain snap, grid, polar & modification tool like erase etc. not contain on status bar.
  - All of the axes in 3D coordinate system meet at 90°.
  - First angle orthographic projection viewed from one side and placed on other side of front view.
  - A user can adjust the drawing by limit command to control the size of drawing area.
  - In third angle orthographic projection, a plan is placed either above or below the front view depending upon weather the viewing is from above or below.

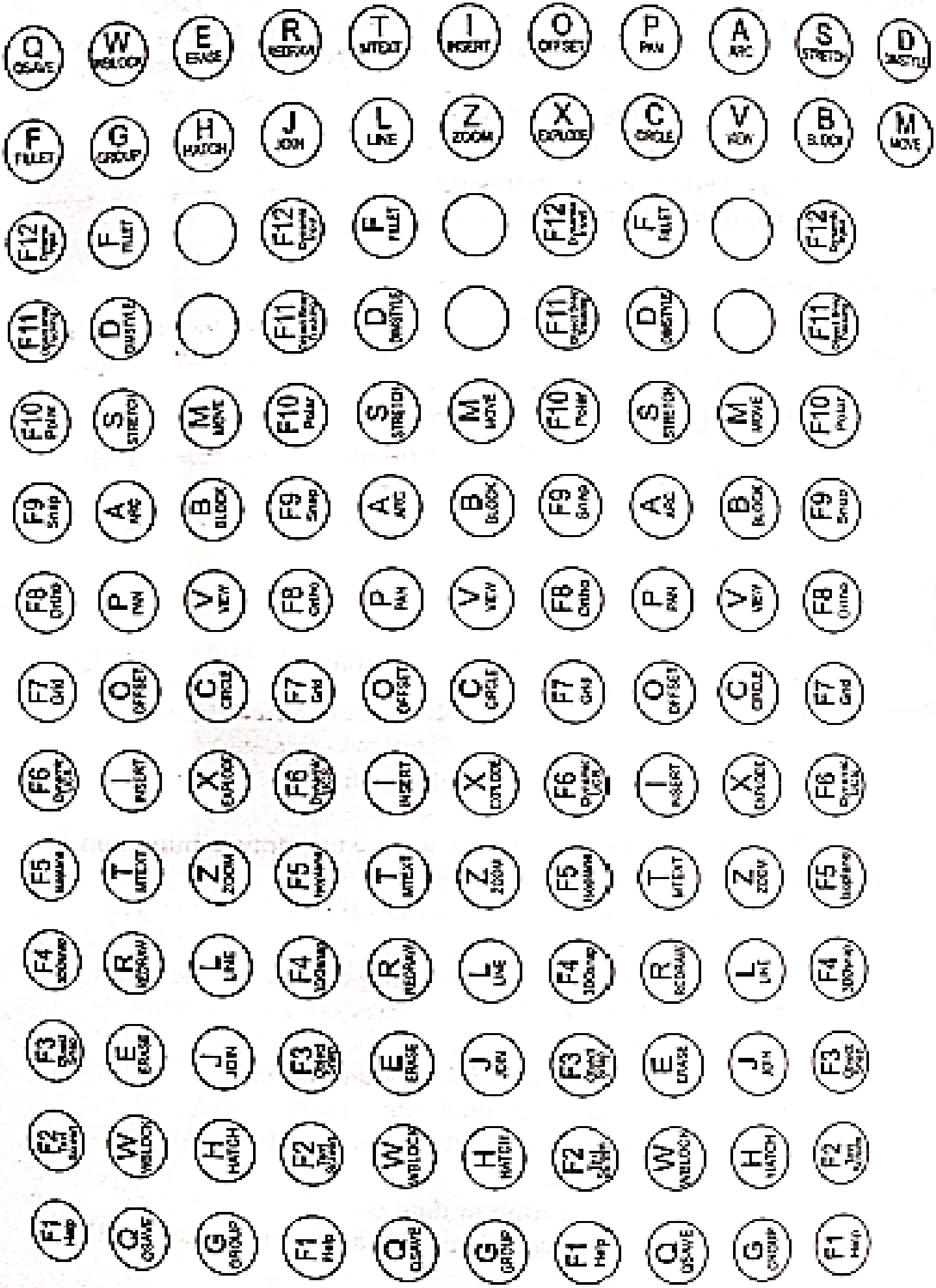


❖ Toggle General Features

Ctrl + d	Toggle coordinate display
Ctrl + g	Toggle Grid
Ctrl + e	Cycle isometric planes
Ctrl + f	Toggle running object snaps
Ctrl + h	Toggle Pick Style
Ctrl + Shift + h	Toggle Hide paletts
Ctrl + I	Toggle coords
Ctrl + Shift + I	Toggle infer constraints

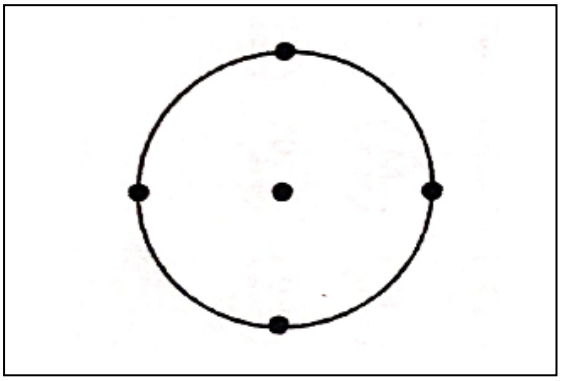
❖ Manage Screen

Ctrl + 0 (zero)	Clean Screen
Ctrl + 1	Property Palette
Ctrl + 2	Design Centre Palette
Ctrl + 3	Tool Palette
Ctrl + 4	Sheet Set Palette
Ctrl + 6	DB Connect Manager
Ctrl + 7	Mark-up Set Manager Palette
Ctrl + 8	Quick Calc
Ctrl + 9	Command Line

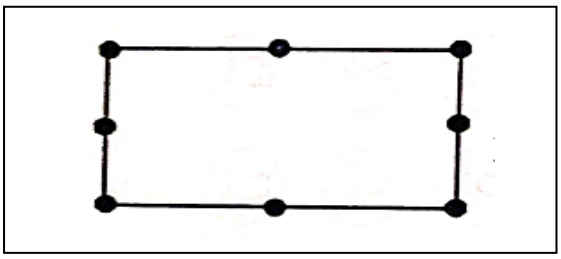

Q QSAVE
W WBLOCK
E ERASE
R REDRAW
T MTEXT
I INSERT
O OFFSET
P PAN
A ARC
S STRETCH
D DIMSTYLE
F FILLET
G GROUP
H HATCH
J JOIN
L LINE
Z ZOOM
X EXPLODE
C CIRCLE
V VIEW
B BLOCK
M MOVE
F12 Help
F11 Object Snap
F10 Polar
F9 Snap
F8 Ortho
F7 Grid
F6 Dynamic UCS
F5 Isoplane
F4 3DOsnap
F3 Osnap
F2 Text Window
F1 Help

❖ Important Points in Auto Cad-

- Origin of Drawing is at (0, 0)
- Modern CAD system are based on ICG (Interactive Computer Graphics)
- UCS - User Co-ordinate system
- WCS - World Co-ordinate system
- LTS - Line Type Scale Command
- CAM - Computer Aided Manufacturing
- Grip point



Circle Has 5 Grip point



Rectangle has 8 Grip Point

- We need 2 points to define Rectangle command.
- 1 Auto Cad objects in a Rectangle.
- Using Polygon Command in Auto Cad, we can draw minimum 3 and maximum 1024 sides of polygon.
- Minimum Allowable layers in a drawing - 1
- Objects are rotate around the base point.
- One quick way to view the entire drawing area is use the zoom command by Type Z enter A enter
- Grid spacing in X & Y direction is 10.
- Ortho mode allows the user to draw 90° straight lines.
- Input Devices in Cad can be divided into 3 parts.
- Newman & Sproull formulated 6 ground rules to be considered in designing graphics software.
- Cad & Cam are tied by a common data base:
- To obtain parallel lines, concentric circles and parallel curves off set is used.