-L Characteristics of Soil.

1. *Soil* : unconsolidated earth material.
2. *Soil Mechanics*: deals with the action of forces on soil and with flow of water in soil.
3. *Soil Engg*: applications of principles of soil mechanics to practical problems.
4. *Geotechnical Engg*: deals with Engg. Problems includes Site Investigations, design & construction of foundations, earth retaining structures etc,.
5. *Scope of Soil Engg*: i). **F**oundations ii) **R**etaining Structures iii). **E**arth Dams iv) **S**tability of Slopes v). **U**nderground Structures vi) **P**avement Design. **(FRESUP)** **hint.**
6. *Residual soil:* Soil which stays just above the parent rock
7. Transported Soil: Soil which stays away from the parent rock.
8. Soil Types: **(SSC-MLC-BP)**hint
   1. Sand - CGS, particle size(0.075mm to 4.75mm), Visible, C=0, Pervious.
   2. Silt - FGS, particle size (0.002mm to 0.075mm), not visible.
   3. Clay - Very fine, < 75µ, shrinkage & swelling.
   4. Murrum – Powdered, small pieces of disintegrated rock.
   5. Loess – Wind deposit(Aeolian), 0.01 to 0.55mm, porous & unstratified.
   6. Caliche – (G+S+M) cemented by Calcium Carbonate.
   7. Bentonite – high % of Clay mineral "Montemorilionite", highly plastic(volcanic ash) – high shrinkage & swelling.
   8. Peat – Organic Soil – Vegetable Matter – Excess Moisture-Swamps.
9. Indian Soils: **(ABCD – MLA)**hint
   1. Alluvial Soils – North India, S.M.C alternative layers, transported by rivers, low ρ,
   2. BC Soils
   3. Desert Soils
   4. Marine Soils
   5. Lateritic Soils .

10. Mech. Analysis – <u>Sieve Analysis:</u>
    1. Dry Sieve Analysis
    2. Wet Sieve Analysis

    <u>Sedimentation Analysis:</u>
    1. **Hydrometer method**
    2. Pipette method
    3. Plummet balance

11. In **Hydrometer method** the diameter of particles under suspension at any time t after starting test is given b

$$D = \sqrt{\frac{30\mu}{980\left(G_s - G_w\right)}}\sqrt{\frac{H_R}{t}}$$

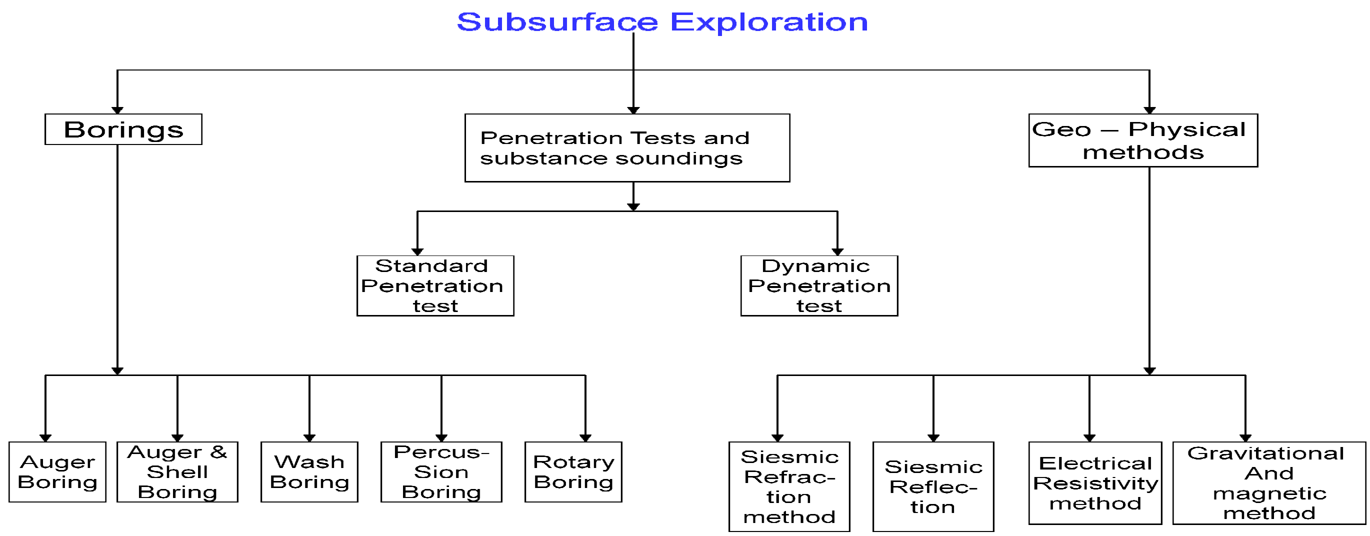
The percentage (N) of particles finer than d is given by

$$N = \frac{100G_s}{W_h\left(G_s - G_w\right)}\left(R_h + C_t - C_d\right)$$

Temperature Correction $R_h = R_{ht} - 25 \times 10^{-6}(T - T_c) + (G_T - 1.0)$

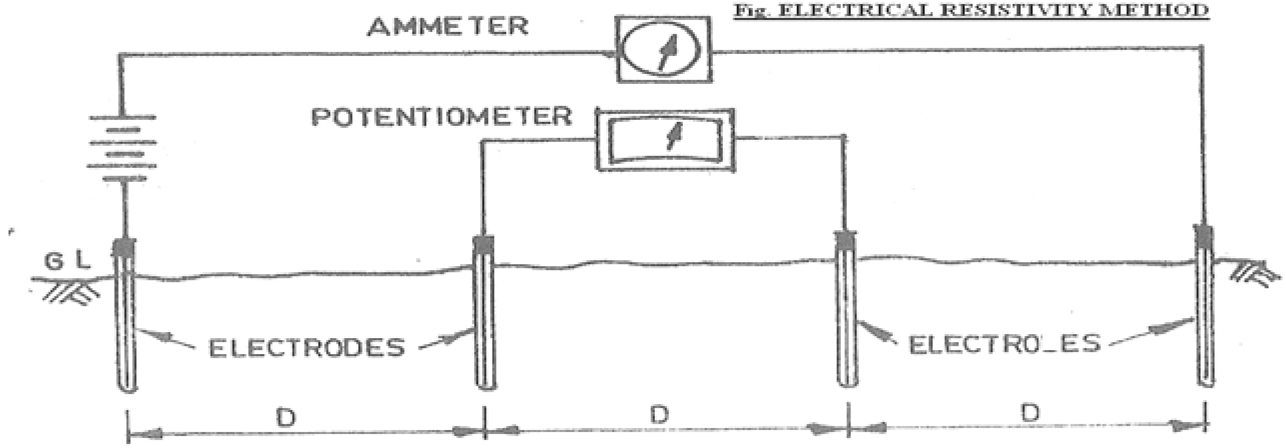
IL Soil Exploration.

1. Methods of Exploration a). Reconnaissance b). Preliminary Explorations c). Detailed Exploration
2.



3. Electrical Resistively Method

Fig. ELECTRICAL RESISTIVITY METHOD



4. Seismic method

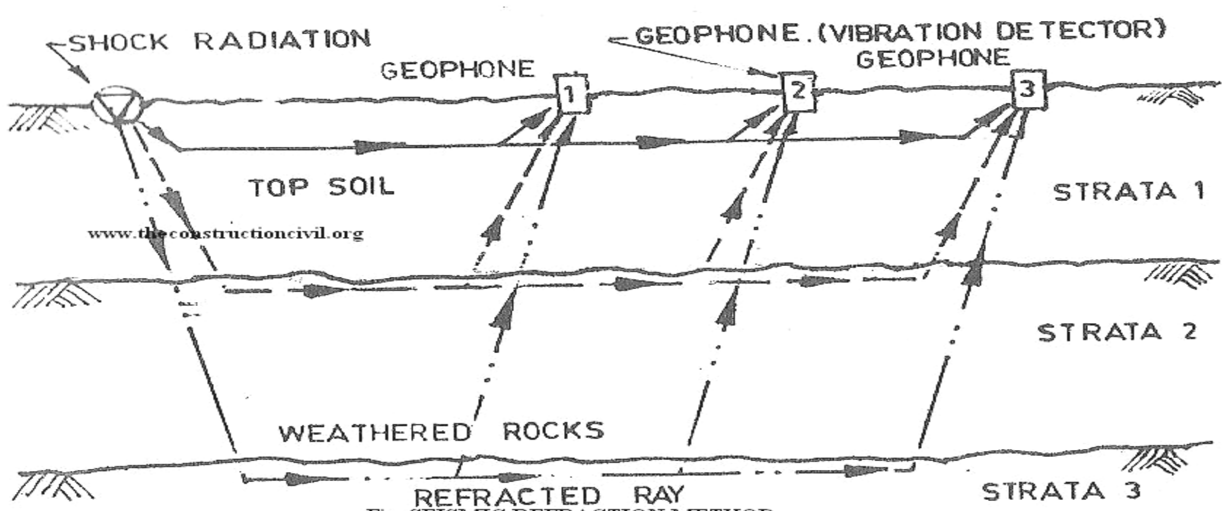


Fig. SEISMIC REFRACTION METHOD

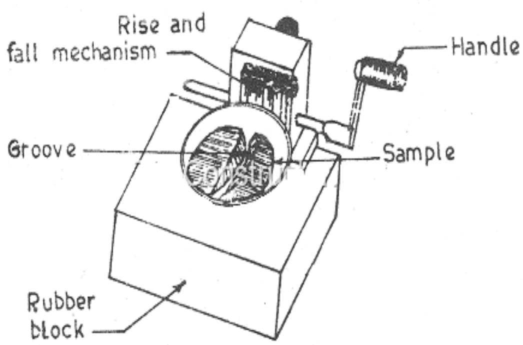
III. Essential properties of soils

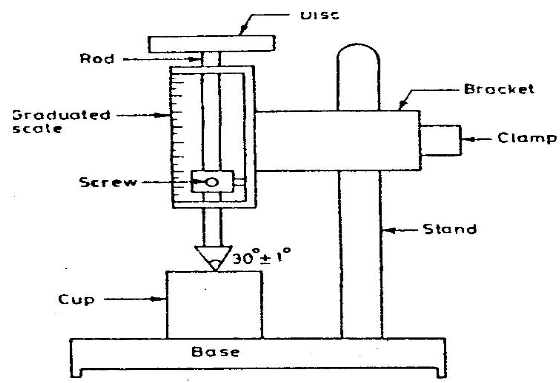
1. Types of sampling : 1. Disturbed sampling --- Direct excavations, Augers ,Thick wall samplers
2. Undisturbed sampling --- Standard sampler etc,.

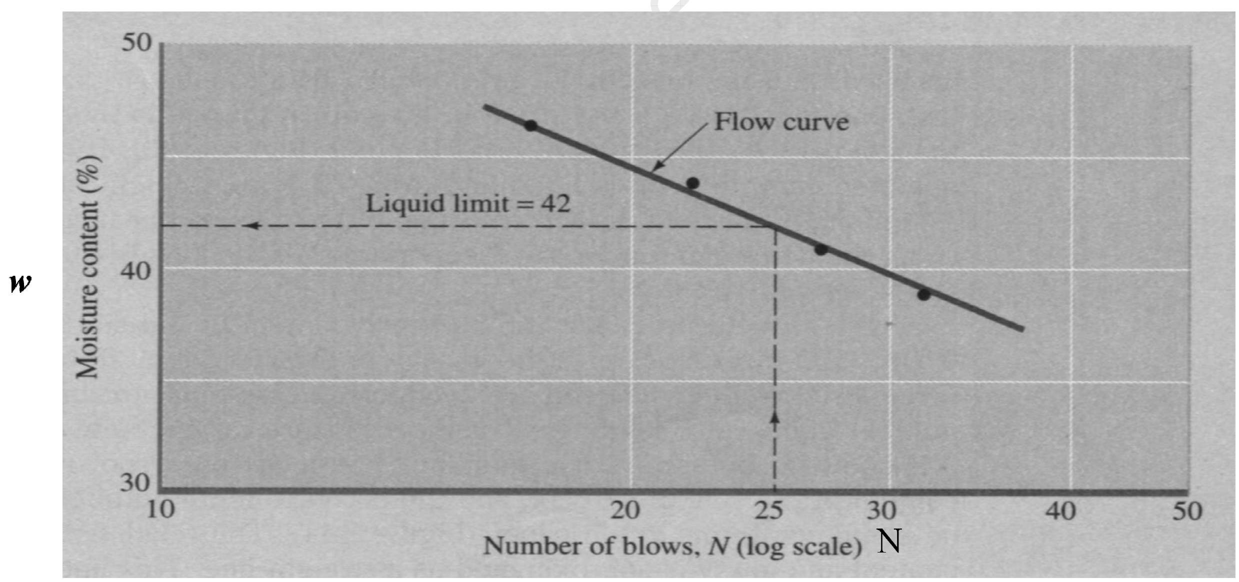
2. Soil moisture content = $\frac{W_w}{W_s}$ x 100

3. The water contents at which the soil changes from one state to the other are known as consistency limits or Atterberg's limits -- 1. Liquid limit. 2. Plastic limit 3. Shrinkage limit

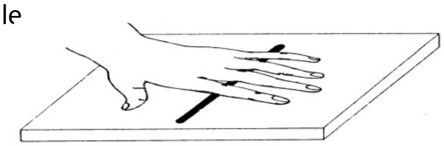
4. Liquid Limit: Minimum water content at which, the soil, cut by a groove of standard dimensions, flows together by 12mm, when jarred twenty five times. ↓ τ, determined by Casagrande's & Method Static Cone penetration





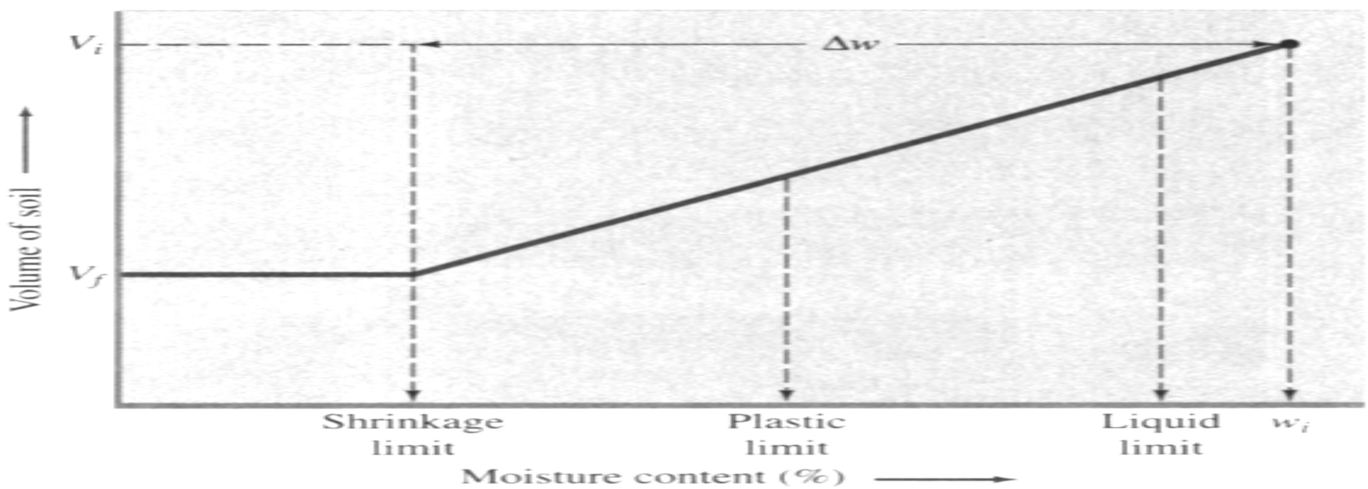


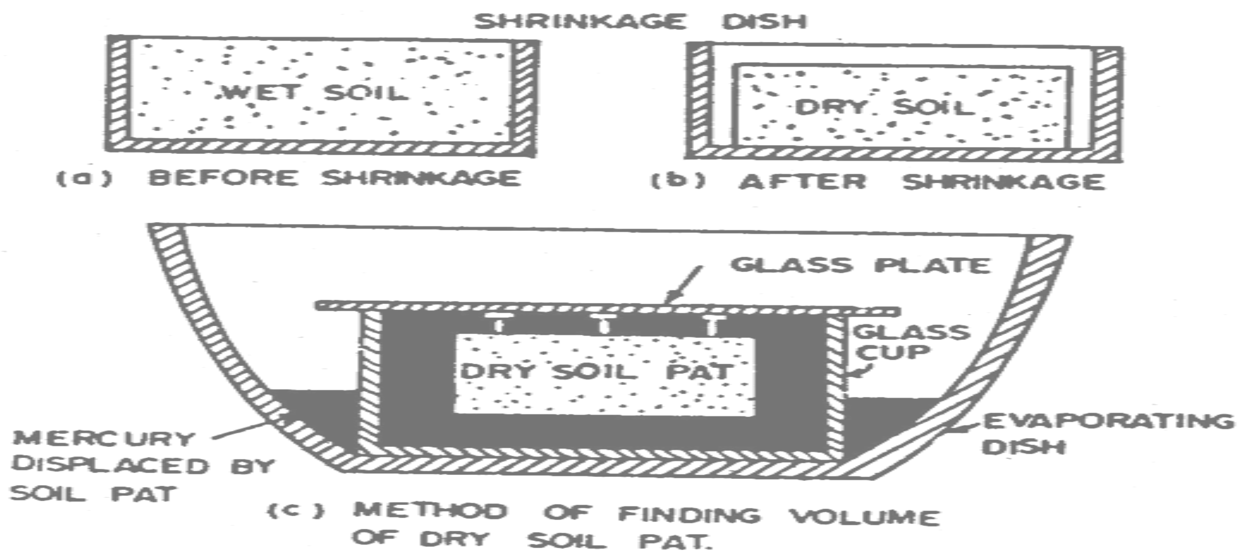
Plastic Limit: minimum water content at which a soil will just begin to crumble when rolled into a thread of approximately 3 mm in diameter



Plasticity Index : **(PI) = W_L - W_P** it gives plastic Range

Shrinkage Limit(SL) : The water content at which the soil volume ceases to change





Shrinkage limit W_s = $\dfrac{(M_1 - M_s) - (V_1 - V_2)\,\gamma_w}{M_s}$

where M_1 = Mass of wet soil(g), M_S = Mass of dry soil after shrinkage

V_1 = Volume of wet soil in ml, V_2 = Volume of dry soil after shrinkage in ml,

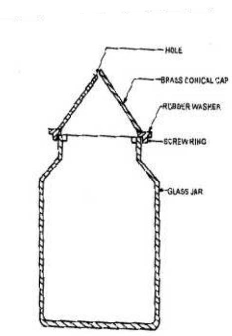
γ_w = Specific weight of water

Shrinkage Index $I_S = I_P - W_S$

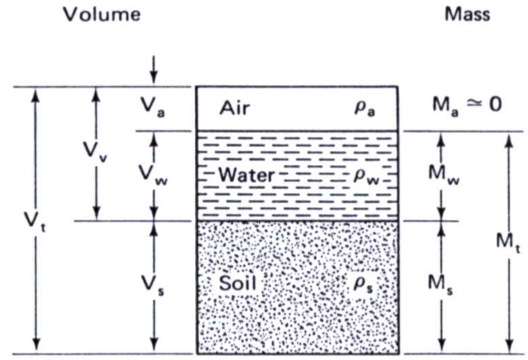
5. Specific Gravity of Soil: the ratio of the weight of given volume of soil solids to the weight of an equal volume of distilled water @ same temperature. Determined by Pycnometer Method

$$\therefore G = \frac{(M_2 - M_1)}{[(M_4 - M_1) - (M_3 - M_2)]}$$

where M_1= Mass of bottle
M_2= Mass of bottle + soil
M_3= Mass of bottle + soil + water
M_4= Mass of bottle + water



6. Three Phase System of Soil



$(V_v) = V_w + V_a$ $\quad W = \dfrac{W_W}{W_S} \times 100$

$\Upsilon = M/V$ (N/mm³ or KN/m³) ; $\Upsilon_d = M_s/V$ (N/mm³ or kN/m³)

$\Upsilon_{sat} = \dfrac{M_{sat}}{V}$; $\Upsilon_{sub} = \dfrac{M_{sub}}{V}$; $\Upsilon_{sub} = \Upsilon_{sat} - \Upsilon_w$; $G = \dfrac{\gamma_d}{\gamma_w}$

$e = V_v/V_s$; $\quad e = n/(1-n)$

$n = V_v/V \times 100$; $\quad n = e/(e+1)$

$S_r = \dfrac{V_w}{V_v} \times 100 \qquad n_a = \dfrac{V_a}{V} \times 100 \qquad a_c = \dfrac{V_a}{V_v} \times 100 \qquad I_D = \dfrac{e_{max} - e}{e_{max} - e_{min}} \times 100$

7. Relations:

$e = \dfrac{WG}{S_r} \qquad \Upsilon_b = G_s \Upsilon_w \dfrac{(1+w)}{(1+e)}; \qquad \Upsilon_d = G_s \Upsilon_w \dfrac{1}{(1+e)};$

$\Upsilon_b = \Upsilon_w \dfrac{(G+e.S)}{(1+e)}; \quad \Upsilon_{sub} = \Upsilon_w \dfrac{(G-1)}{(1+e)}; \qquad \Upsilon_d = \dfrac{\Upsilon b}{(1+w)}$

IV. Classification of soils

1. Purpose & Classification of Soils.
   Preliminary classification or Descriptive classification; Classification by Origin
   Classification by **structure;**
   Unified soil classification,
   Indian Standard soil classification.

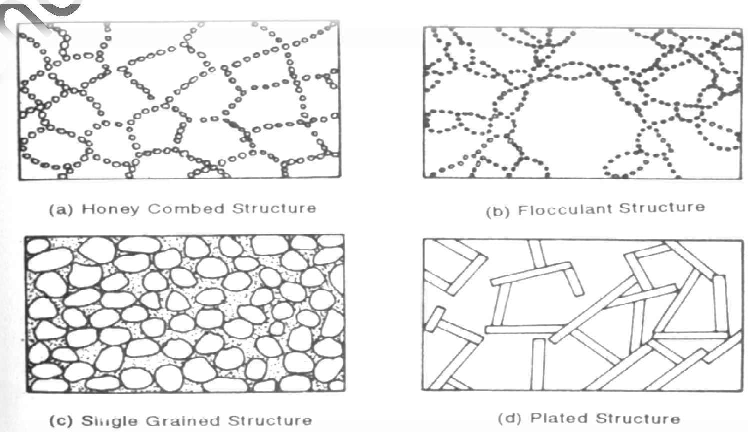
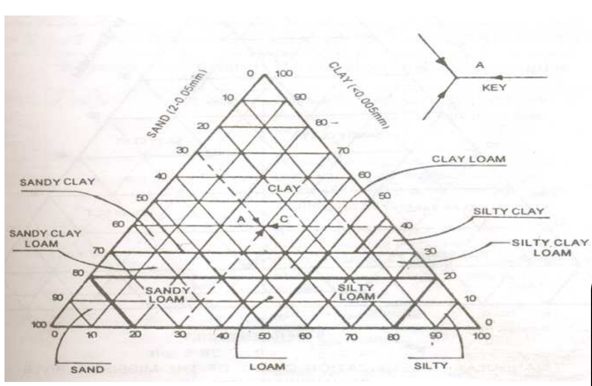


Fig. 3.0 STRUCTURE OF SOIL

2. Textural classification of soils classification



of soils based on particle size distribution is known as textural classification percentage of sand, silt and clay making up the soil are taken in to account

2µ	75µ	4.75mm	80mm	300mm	
Clay	Silt	Sand	Gravel	Cobble	Boulder

3. I.S Classification: Based on grain size analysis & Physical properties of soil
   Derived from Unified Soil Classification, used in all Egg. Depts...

4. Soil
   - C.G Soils
     - Gravel (G)
     - Sand(S)
   - F.G Soil
     - Silt (M)
     - Clay(C)
     - Organic Silt/Clay (O)
   - Highly organic Soil

G --- GW	S -- SW	M -- CL	C – CL	O -- OL	
GP		SP	MI	CI	OI
GM		SM	MH	CH	OH
GC		SC			

5. Boundary Classification

C.G Soils -- Gravel or Sand Group GW – GM, GP, GC; GP-GM (why MPC)*

Gravel & Sand Group GW – SW, GM – SM, GP – SP, GC – SC (why MPC)*

F. G Soils – Same Compressibility: CL – ML, ML – OL, CL – OL
CI – MI, MI – OI, CI – OI
CH - MH, MH –OH, CH - OH
} (**CM MO**ttam **Co**operation)*

B/W Low & Intermediate Compressibility CL-CI, ML-MI, OL-OI (CMO)
B/W High & Medium Compressibility CI-CH, MI-MH, OI-OH (CMO)
} CM Operation/Chief Mng Ofc.

B/W C.G & F.G Soils SM-ML, SC-CL

<u>V. Hydraulics & Mechanical Properties of Soil</u>

1. **Permeability of Soil (K):** Flow of water/fluid through it, for pervious soil K value is High, impervious K value is Less.

K Importance: for Calculating Settlement of buildings, yield of wells, seepage values etc,. Units: mm/sec, m/day..

Stability of Slopes, in filter design to prevent piping in Hydraulic Structures.

Formula: $v = \frac{q}{A} = k\,i$ Where q = discharge per unit time, A = Total Cross Sectional area of Soil mass,
i = hydraulic gradient, k = Darcy's Coefficient of permeability
v = velocity of flow, or average discharge velocity

2. ***Factors affecting Permeability:***

1. Particle Size	: Size ↑ – K ↑ (Size α K)
2. Particle Shape	: Angular – K ↓, rounded – K ↑
3. Void Ratio	: e α K
4. Sp. Surface Area	: K α 1/SSA
5. Degree of Saturation	: Fully Saturated Soil K ↑ than Partially Saturated
6. Adsorbed Water	: K ↓

3. Tests to determine K

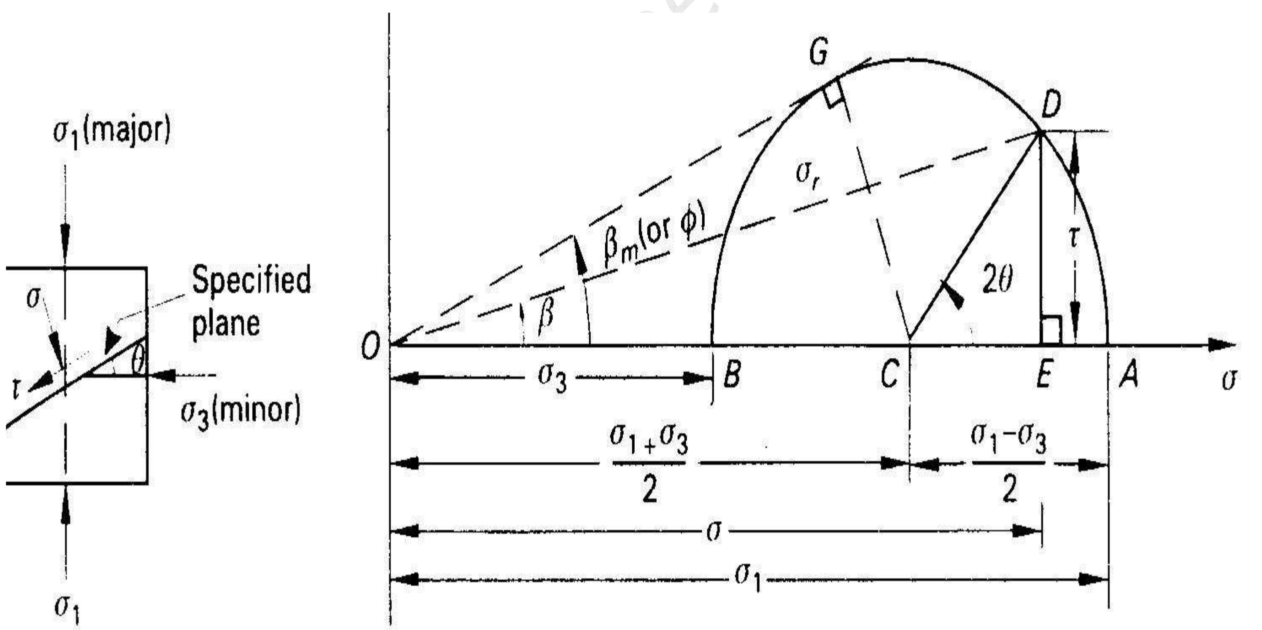
Lab tests (Not Reliable)	Field Tests (Reliable)
1. Const. Head Method	1. Pumping Out Test
2. Variable Hd. Mthd.	2. Pumping In Test
3. Capillary permeability	
4. Consolidation Test	

4 **Compressibility:** The decrease in volume of a Soil mass under pressure (Compressive force).
Solid particles compression is negligible & water is incompressible
Air Voids in dry & partially saturated soil is expelled quickly as soon as load applied on it.
Decrease of Volume takes due shifting of position of solids as air escapes from voids.
It is useful in determining the magnitude & time of settlement of structure

5. **Consolidation**: Compression of Saturated Soil due to expulsion of water from voids under a steady static #
6. **Shear Strength**: Max. resistance to shear stresses just before the failure of the soil.
Depends on Cohesion or Adhesion of soil particles, frictional resistance, particles interlocking
Shear parameters (C, Φ) depends on loading, Water content & Testing Conditions
7. **Principal Plane & Stress**: plane where shear stress $\tau = 0$, but having only Normal Stress σ
Principal Stress is the Normal Stress acting the Principal Plane.

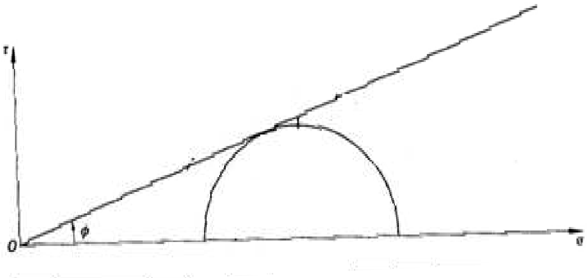
In the following figure

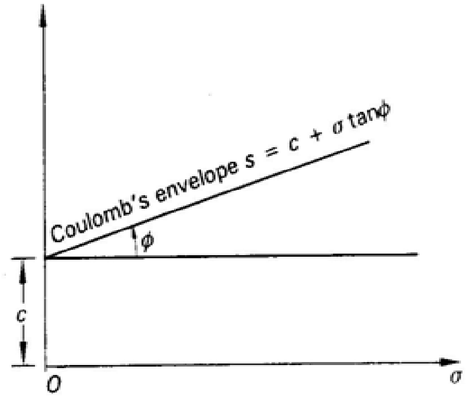
σ_1 is Major principal stress
σ_2 is Intermediate principal stress, and
σ_3 is Minor principal stress



8. Mohr's Circle: It is a graphical Method to determine Stresses on a plane inclined to Principal Plan
Circle is drawn by taking mid point of Major & Minor Stresses
Each point on it gives Shear & Normal Stresses.

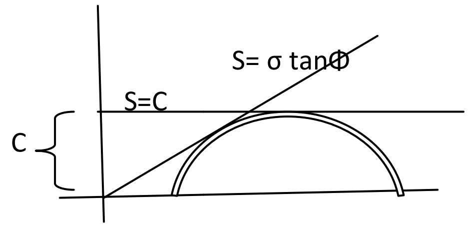
9. Mohr's Theory of Failure: Here failure is due Normal & Shear Stresses
Shear failure is function Normal Stresses i.e $\tau(f) = f(\sigma)$





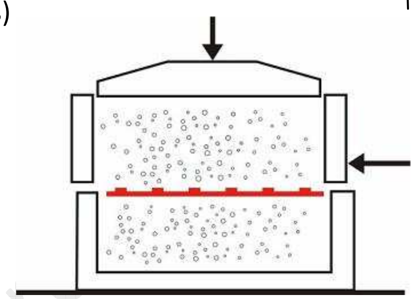
10. Coulomb's Theory of Failure: Shear Strength depends on (C & Φ) shear parameters.

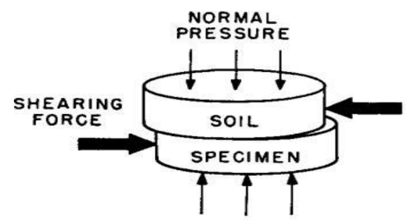
    Linear function of Normal Stress on the plane $\tau = C + \sigma \tan \Phi$



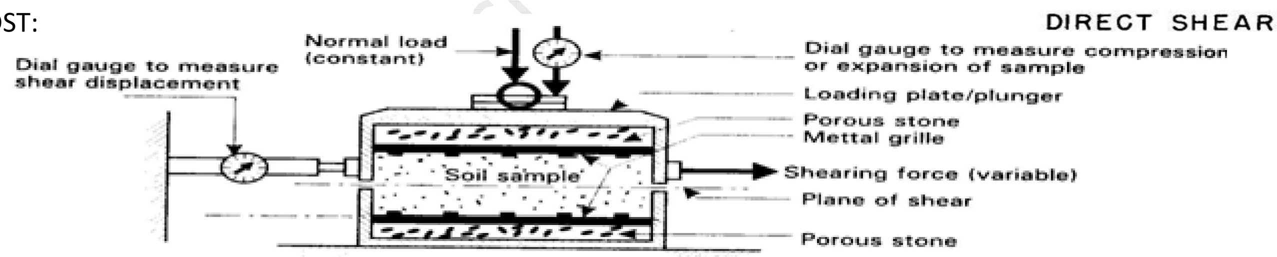
11. Mohr- Coulomb Theory of failure:
    Mohr's failure criterion + Coulombs eqn., Curve → linear
    Curve become flatter with increase in σ_n

12. Determination of Shear Strength (Lab Tests)
    1. DST (Direct Shear Test)
    2. TST (Triaxial Shear Test)
    3. RST (Ring Shear Test)
    4. VST (Vane Shear Test)
    5. UCT (Unconfined Compression Test)
    6. TT (Torsion Test)



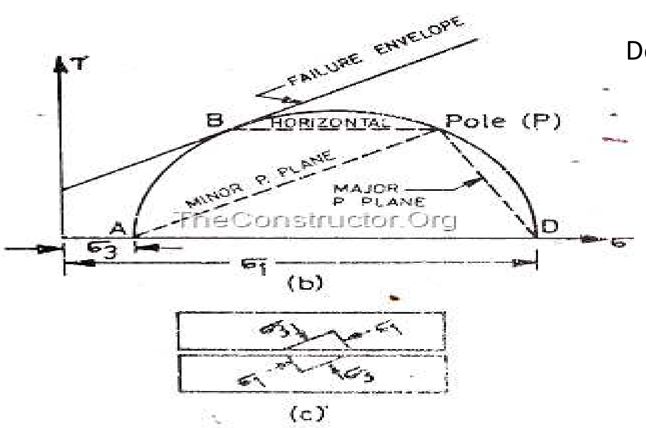


13. DST:



Finding Shear parameters, also called as Box Shear Test

Soil Specimen of Size 60 x 60 x 25 mm



Merits: Simple Test, Performed under drained #'s

Demerits: Stress Distribution is very complex
Area under shear decreases gradually while testing
Failure plane (Horizontal) Is the weakest plane
Only drained tests can be conducted on highly Permeable soils

14. Tri-Axial Compression Test:

Finding Shear parameters

Sample Height : 2 to 2.5 x d of sample

$\sigma_c = \sigma_1 - \sigma_3$

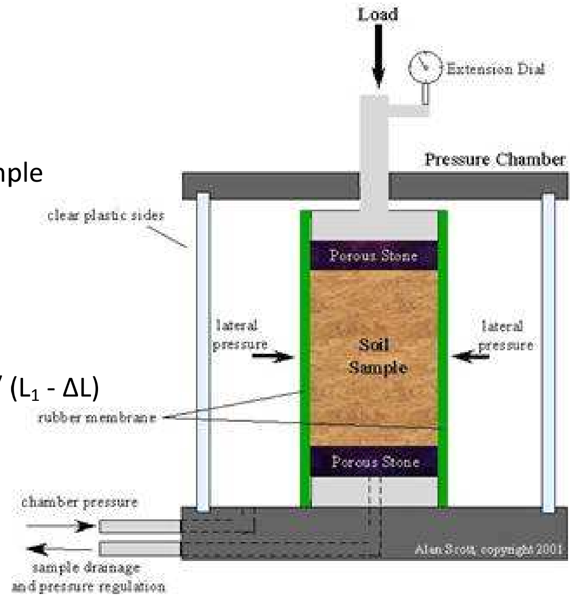
= Axial load / failure Area

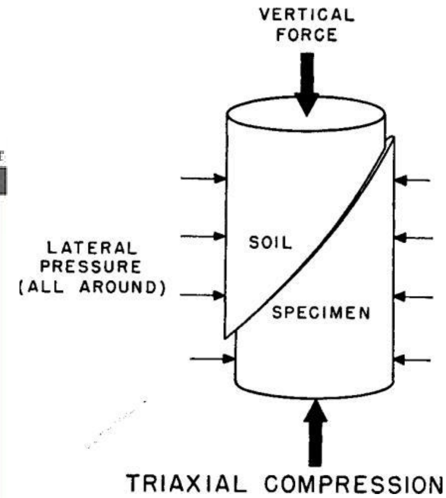
Where Failure Area $A_2 = (V_1 \pm \Delta V)/ (L_1 - \Delta L)$

V_1 → initial Volume

ΔV → change in volume

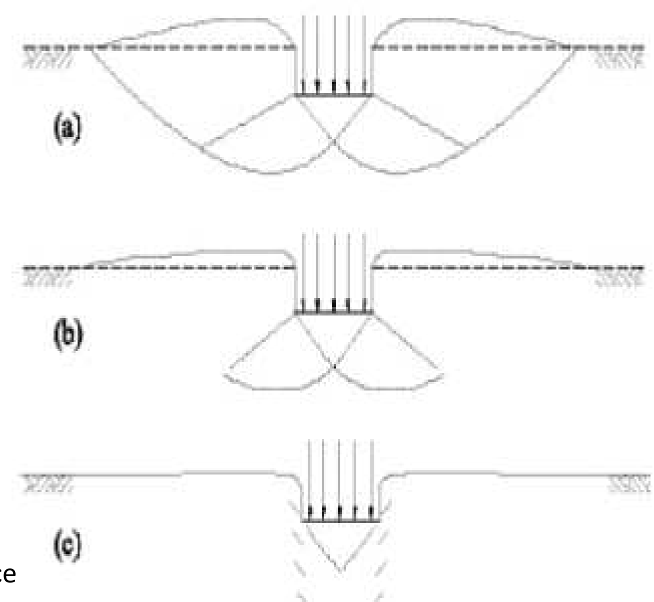
ΔL → change in length





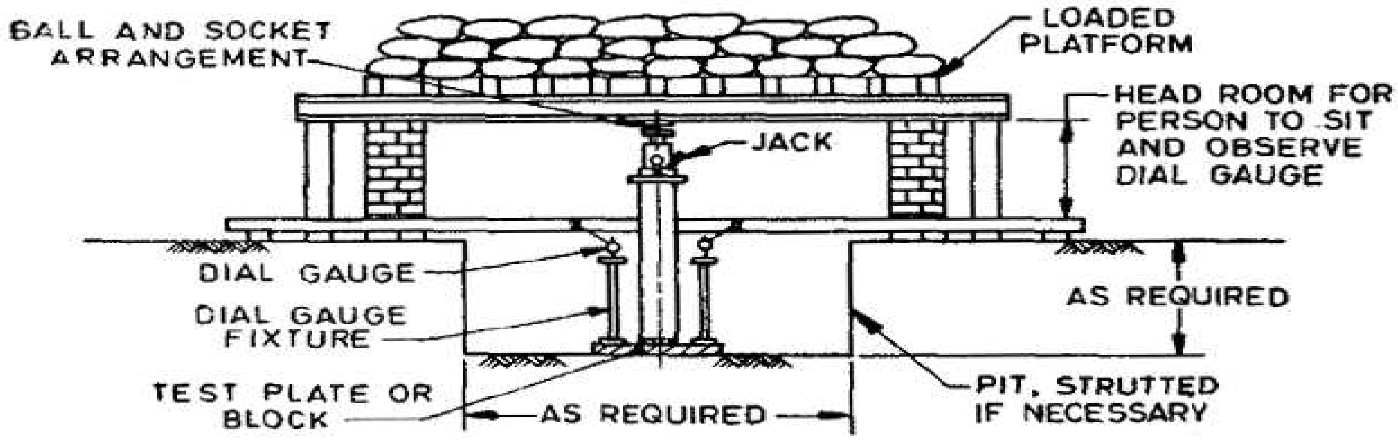
VI. Bearing Capacity of Soil:

1. Defn. of B.C of Soil: Ability to support or counteract the impose load
2. Importance: To ensure the safe Bearing Capacity of Soil, for loading very important parameter in design
3. Depth of Foundation depends/placed @ Hard Strata of Soil where soil under goes no vol. change, no frost action, no scouring action, minimum depth is 50cm below NGL.
4. Design of Foundation: Means it should safe against failure of the soil by shear Safe against failure of the structure due to settlement of soil. It is require to determine the Safe B.C of Soil below the foundation upto a depth of 1.5 to 2 times the breadth of foundation.
5. Shear Failure Modes:
   a) GSF : (General Shear Failure)
      Slight downward movement
      Soil bulges out at surface
      Occurs in dense sand & stiff clays
   b) LSF: (Local Shear failure)
      Large deformation below footing
      Bulging occurs after vertical settlement
      Occurs in medium dense sand , Clays
   c) PSF: (Punching Shear Failure)
      Failure surface don't extend upto ground surface
      No buldging, occirs in loose sand or soft clay



6. Determination of B.C of soil: It depends on 1. Soil type & Its properties, 2. Foundation type, 3. Local ground water level. Field Tests: Load tests (PLT), Penetration Tests (SPT)

7. Plate Load Test:



Not suitable for clays, used to find Ultimate Bearing Capacity & Settlement

MS Plate – 25mm thk

Min Size: 30 x 30 cm for gravel, dense Sand

Max. Size: 75 x75 cm

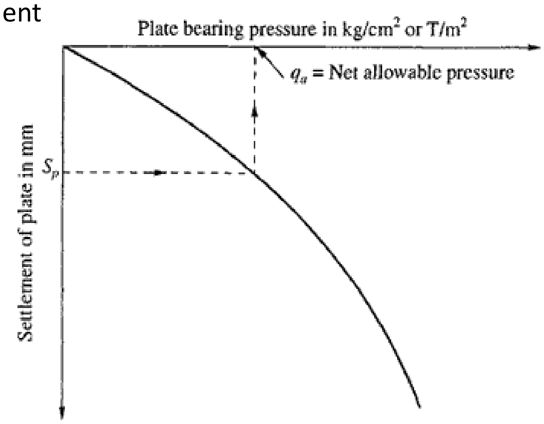
Generally 6 x 60 cm is used for Clay, Silt, Sandy type soils

Permissible settlement of the footing may be calculated from the settlement of the plate

$$S_f = S_p\left[\frac{B[B_p + 0.3]}{B_p(B+0.3)}\right]^2$$

Where S_f = settlement of footing,

S_p = settlement of test plate, B = width of footing, B_p= width of test plate



8. Importance of Factor of Safety & Safe bearing Capacity of Soil:

Soil never loaded to its Ultimate B.C at which soil fails for this purpose a FOS is adopted this value is called SBCS

Safe bearing capacity = Ultimate bearing capacity / Factor of safety

9. I.S Code Equation for Computing Bearing Capacity of Soil

$$q_u = C\, N_c .s_c .d_c .i_c + \gamma\, D\, (N_q - 1)\, s_q .d_q .i_q + 0.5\, \gamma\, B N_\gamma .\, s_\gamma . d_\gamma .\, i_\gamma .\, W'$$

Where q_u = Net ultimate bearing capacity, C = Cohesion of the soil, Ø = Angle of shear resistance of the soil

γ = Effective unit weight of soil, B = width of foundation , S_c, S_q, S_γ are the shape factors,

d_c, d_q, d_γ are the depth factors, i_c, i_q, i_γ are the inclination factors

Determination of W' : if $Z_w \geq B$ then W' = 1

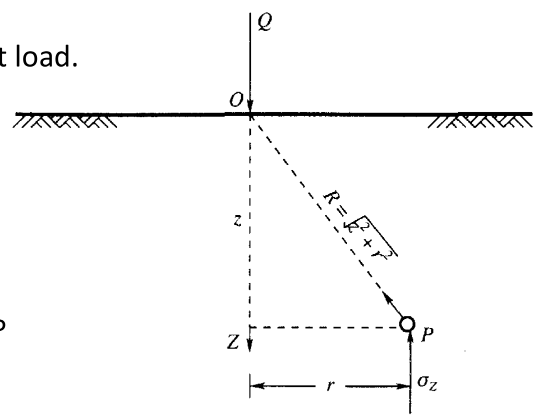
If $Z_w = B$ then W' = 0.5

If $Z_w < B$ then W' = 1

Stability of Slopes: Should be against Gravity, Seepage forces, Seismic forces.

VII. Settlement of foundation:

1. Settlement:
   The vertical displacement or sinking of the structure takes place due to compression & deformation of underlying soil
2. Causes for Settlement:
   Static, moving – loads
   Consolidation, lowering the ground water table
   Undermining, underground erosion
   Seasonal volume changes in soil like clay.
3. Remedies:
   By increasing footing area, by pre-consolidation
   By designing the structure as rigid member
   Construction on Cohesive soils may be carried out slowly as it require more time for expulsion of water from voids.
4. Types:
   1. Uniform Settlement : same settlement @ diff. points, structural stability can be ensured
   2. Differential Settlement : diff. Settlements @ diff. points, results in cracking or failure of structure
5. Stress Distribution theories:
   1. Boussinesq's
      Assumptions: The soil medium is elastic, homogeneous, isotropic and semi-infinite
      The self-weight of the soil is not considered
      The load acting on the ground surface is a point load.
6. Stress due to point load at the surface – Boussinesq's theory



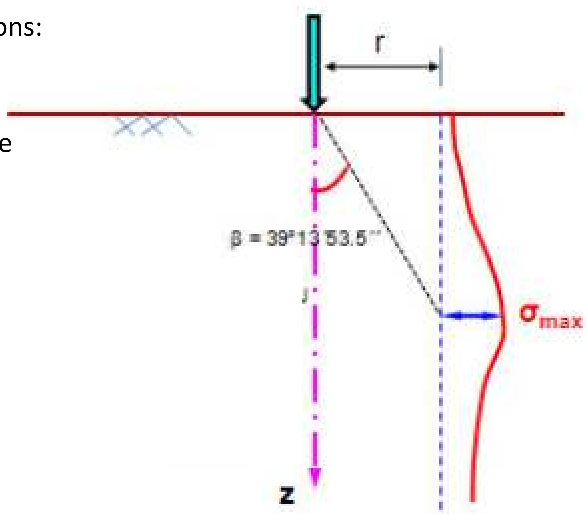
$$\sigma_z = \frac{3Q}{2\pi z^2}\frac{1}{[1+(r/z)^2]^{5/2}}$$

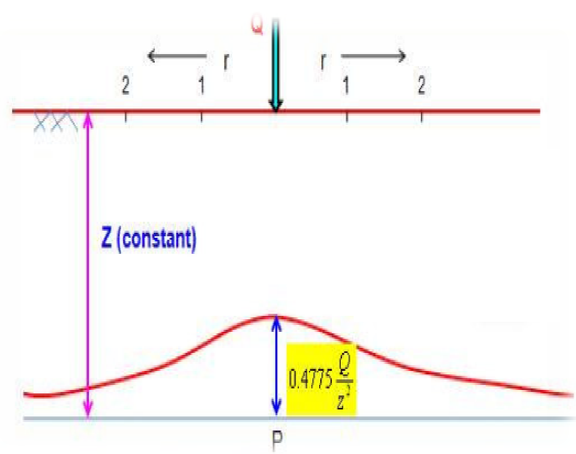
Where Q = point load

r = polar radial coordinate of point P

7. Stress Variations:

On Vertical Plane





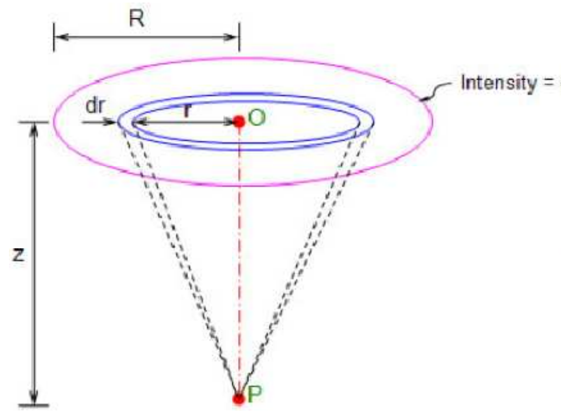
On Horizontal plane

8. Vertical pressure under a uniformly loaded circular area

$$\sigma_z = q\left[1-\left\{\frac{1}{1+\left(\frac{R}{z}\right)^2}\right\}^{\frac{3}{2}}\right]$$

Let q = intensity of the load per unit area

And R = the radius of the loaded area



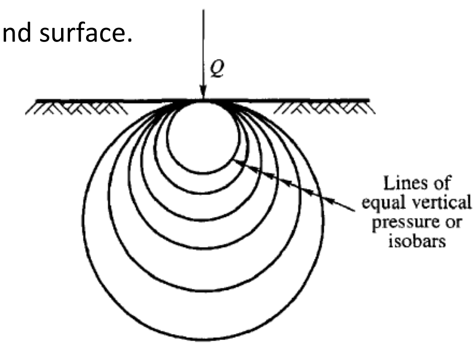
9. **ISOBAR:**

An isobar is a line which connects all points of equal stress below the ground surface.

In other words, an isobar is a stress contour

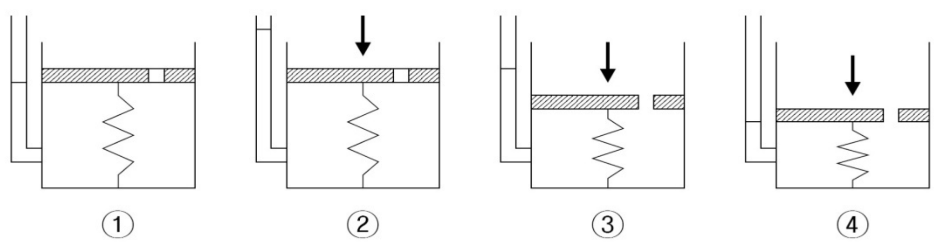
And this zone is called Pressure bulb

Pressure inside an Isobar is greater than pressure on the Isobar



10. Permissible limits: (IS : 1904 – 1961)

Isolated Foundations on Clay : 65 mm
on Sand: 40 mm
Raft Foundations on Clay : 100 mm
On Sand: 40 to 65 mm
Foundations on Clay: 40 mm
On Sand: 25 mm



VIII. Consolidation of Compressive Soils:

1. **Consolidation** is a process by which soils decrease in volume. According to Karl Terzaghi "consolidation is any process which involves decrease in water content of a saturated soil without replacement of water by air.

   Terzaghi Spring Analogy Model

   1. The container is completely filled with water, and the hole is closed. (Fully saturated soil)
   2. A load is applied onto the cover, while the hole is still unopened. At this stage, only the water resists the applied load. (Development of excess pore water pressure)
   3. As soon as the hole is opened, water starts to drain out through the hole and the spring shortens. (Drainage of excess pore water pressure)
   4. After some time, the drainage of water no longer occurs. Now, the spring alone resists the applied load. (Full dissipation of excess pore water pressure. End of consolidation)

2. Field Implications:
   1. Soils with more K value have very little settlement after its construction becoz water gets drained out very quickly
   2. On other side it is quite opposite.
   3. So sound knowledge of Consolidation properties and volume changes of soil is required before the design of Structure to ensure the safety.

IX. Compaction of Soils & Pavement Design :

1. Objectives of compaction: to increase the shear strength (τ) ➔ larger load can be imposed
to decrease the permeability (K) ➔ ↓ expansion / shrinkage
to decrease the compressibility ➔ ↓ settlement
to control the swelling & Shrinkage , ↓ liquefaction

2. Types of field compaction equipment

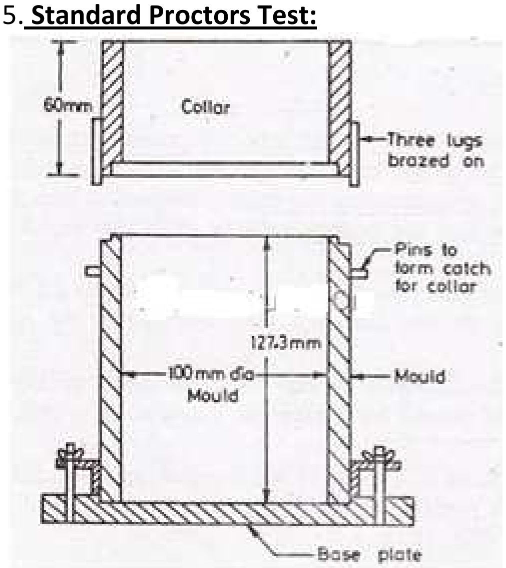
- Smooth-wheeled steel drum rollers
- Pneumatic tyred rollers
- Sheep's foot rollers
- Impact rollers
- Vibrating rollers
- Hand-operated vibrating plate and rammer
- Compactors

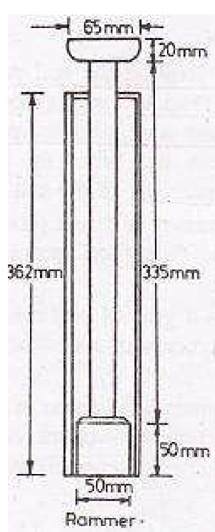
3. Factors affecting compaction: Dry Density, water content, Compactive effort, Soil type

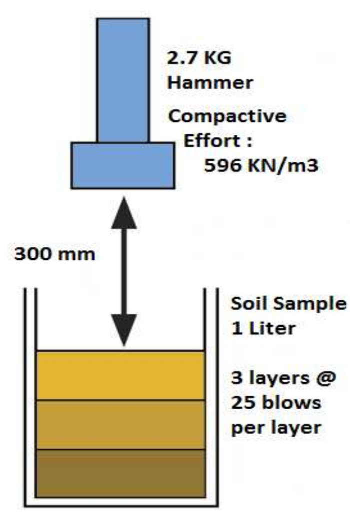
4. Compaction Tests:
RR Proctor (1930) Los Angels developed principles of Compaction while constructing Dams for Water supply work
Compaction tests are conducted to determine the relation between Moisture Content(MC) & Υ_d of soil then Suitability of soil for specific Engg. Purpose may be determined
Important Lab tests:
1. Standard Proctor (AASHTO) Test
2. Modified Proctors (M. AASTHO) Test
3. I.S Compaction Test
4. Direct test
5. Abbots Compaction Test
6. Harvard Miniature Compaction Test
7. Jodhpur Mini Caompaction Test

Important Field Tests:
1. Core-Cutter Method
2. Sand Replacement Method
3. Proctor Needle Method
4. Nuclear Method (Radio Active Isotopes)

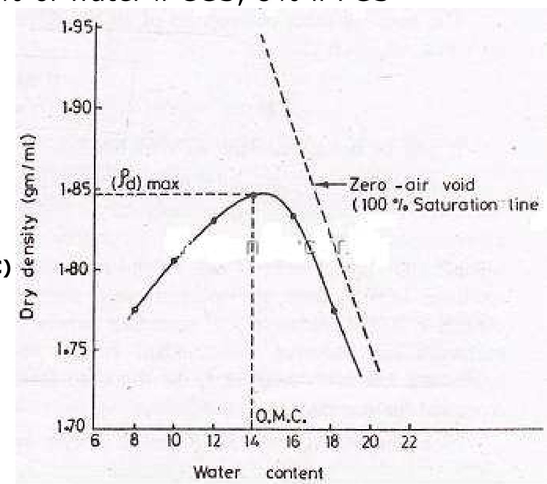
5. **Standard Proctors Test:**







Take about 3kg of air-dried soil. Sieve it through 4.7mm sieve & add 4% of water if CGS, 8% if FGS
If the percentage retained on 4.75mm sieve is greater than 20, use the large mould of 150mm diameter. If it is less than 20%, the standard mould of 100mm diameter can be used
Mould is 105 mm diam. x 115.5 mm high (1 litre) & removable collar-
Hammer is 2.7 kg, drop height 300 mm, Soil placed in mould in 3 layers, each compacted using 25 blows, Total energy delivered = 596 kN.m/m3
Remove collar, Strike off' excess soil, Repeat at different water contents
The dry density is maximum at the optimum water content.(OMC)
A curve is drawn between the water content and the dry density to obtain the maximum dry density and the optimum water content

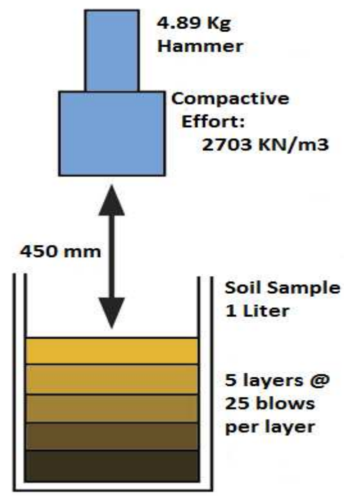


Dry density $= \dfrac{M/V}{1+w}$

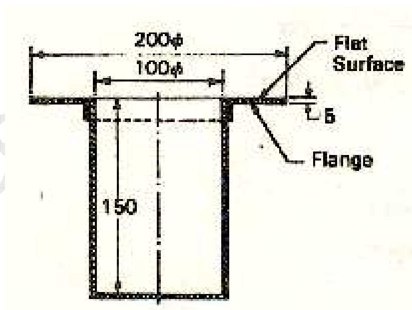
Where M = total mass of the soil, V= volume of soil, w= water content.

6. Modified Compaction Test:

It is standardized by AASHTO => M.AASHTO.
Mould is same but hammer is heavier dropped from greater Height
heavier hammer (4.9 kg), greater drop height (450 mm), same mould (1 litre)
5 layers@25 blows per layer Energy = 2703 kN.m/m3
4.5 times more energy, otherwise, procedure is the same as standard

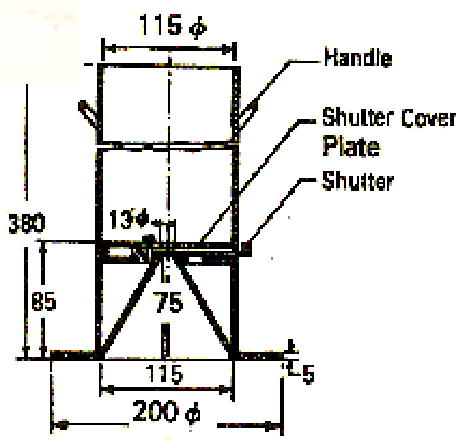


7. Sand Replacement Method.



Sand passing through 600μ & retains on 300μ is taken
Roads and embankments are constructed with soil in layers. Each layer is compacted to maximum density before the next layer is laid over it. The density of each layer is checked by sand replacement method.

Bulk density= Mass of soil excavated / Volume of hole
bulk density of sand = (mass of sand in container) /volume of container
$=(m_1 - m_2 - m_3) / v$ kg / m^3

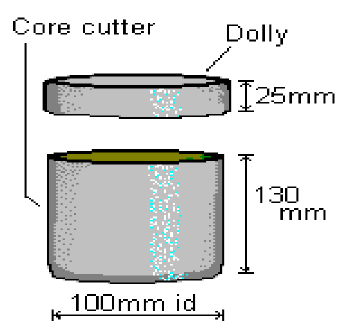


Where m_1 -- Mass of sand pouring cylinder with sand
m_2 -- Mass of sand in cone
m_3 -- Mass of cylinder after filling cone and container
V -- volume of container

Bulk density of soil = Mass of soil excavated / volume of hole
volume of hole = Mass of sand in hole / Bulk density of sand
$= (m_1 - m_2 - m_4) / \gamma_{sand}$

Where m_4 -- Mass of cylinder after filling cone and hole

8. Core Cutter method



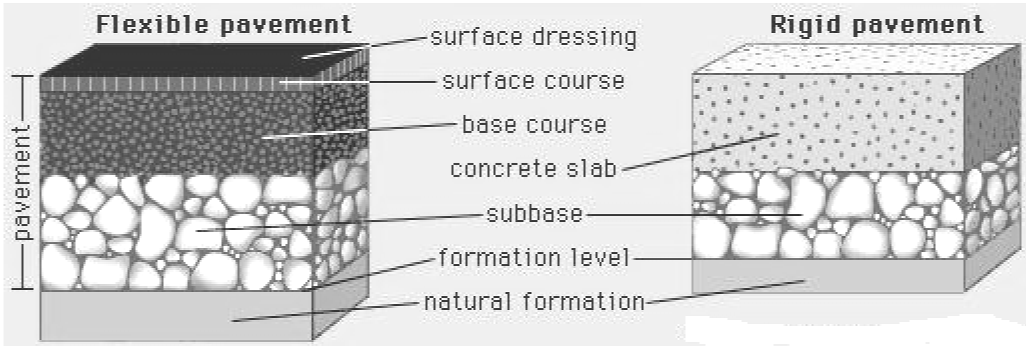
To the mass density of soil in field
CC is a open cylindrical barrel with a hardened sharp Cutting edge
With dolly for ramming into to soil

Mass density of the soil$= \dfrac{M/V}{1+w}$ Where M – Mass of the wet soil in cutter
V – Internal volume of the cutter

9.Pavement Design:

A pavement is a hard crust constructed Over the natural soil for providing a Stable & even surface for the vehicles

It supports & distributes the wheel load & provides adequate wearing surface



Rigid Pavement	Flexible Pavement	Semi Rigid Pavement
It is Made with Cement Concrete	Built on several layers	It has flexural rigidity in b/w them
It have high flexural strength & resist very high tensile stresses	Resist only very small tensile stress bcoz of low rigidity	Made with Pozzolanic Concrete, Lean concrete or Soil Cement
It is capable to bridging the small depressions in subgrade	Subgrade deformation results in change in surface	Resist only moderate tensile stresses

10. California Bearing Ratio (C.B.R) Method

Widely used in the design of pavements for determination of the quality of the subgrade materials underlying the pavement. Test is conducted on prepared specimen

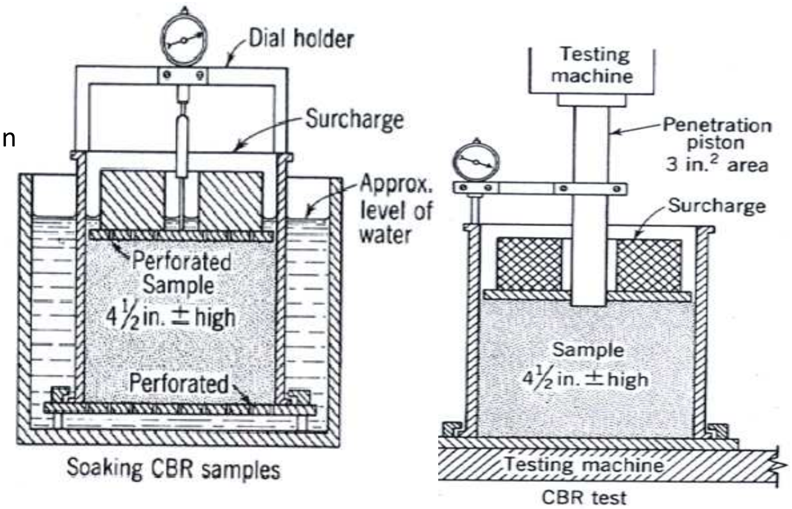
Mould : 150 mm Φ & height 175 mm } effect ht
With base plate & collar } 125 mm

Load is applied thro a plunger 50 mm Φ

Dail Guage – to measure expansion of specimen on Soaking
To measure the penetration

Plunger penetrate @ 1.25 mm/min

Load required for penetration of 2.5 mm & 5 mm is Noted by proving ring

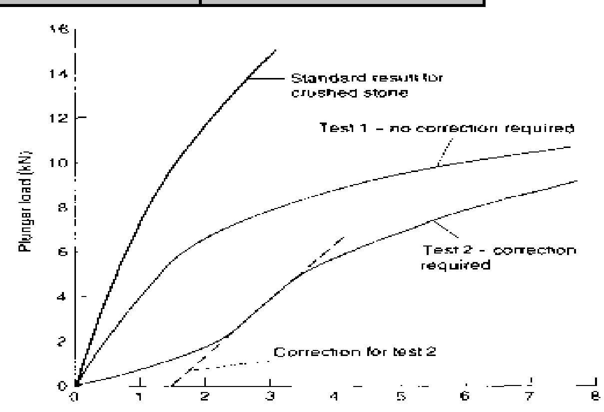


CBR Value = Test Load/Standard Load

Penetration depth (mm)	Standard load (kg)
2.5	1370
5	2055
7.5	2630
10	3180
12.5	3600

Here Test Load is the load at deformation of specimen
Standard load is the deformation load of crushed stone
CBR value @ 2.5 mm & 5 mm is taken and the greater one of the both is taken in design

Plot a load-penetration curve with loads as the ordinate and penetration as abscissa. The curve obtained may be concave upwards at the starting stage due to surface irregularities. Apply a correction to this part by drawing a tangent at the point of greatest slope which will be taken as the corrected curve.



DO UR LEVEL BEST THEN "GOD" WILL SEE THE REST – ALL THE BEST