DAY 04

MIT SYSTEM OF CLASSIFICATION

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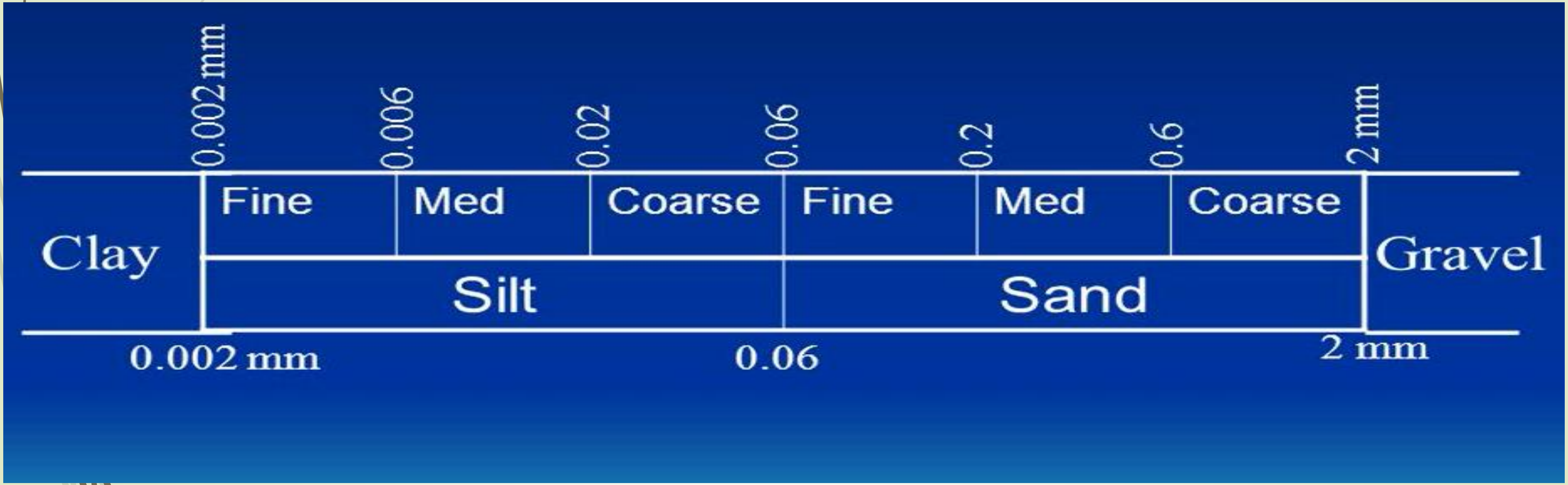


USCS CLASSIFICATION

- It was first developed by Casagrande and later it was modified by Bureau of Reclamation and the Corps of Engineers of the USA..

- Coarse grained soil are classified based on grain size property and fine grained soil are classified on the basis of plasticity characteristics.

USCS CLASSIFICATION

- If 50% of the soil is retained on No.200 (0.075mm) sieve, it is designated as coarse grained soil. There are 8 groups of coarse grained soil.

- If more than 50% of the soil passes No. 200 (0.075mm) sieve, it is called fine grained soil. There are 6 groups of fine grained soil.

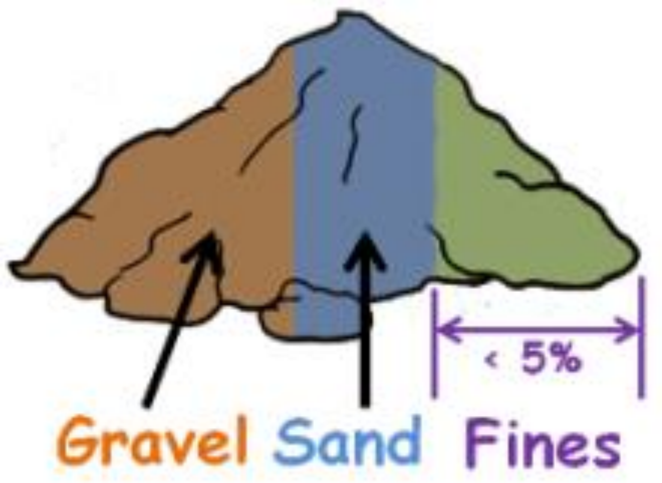
USCS CLASSIFICATION

- Coarse Grained Soil are further classified as **Gravel (G)** and **Sand (S)** using 4.75mm sieve.
- If **more than 50%** of this coarser fraction of soil is **retained on this 4.75mm** sieve then soil is designated as gravels and is denoted with letter G.
- And if more than 50% of this coarser fraction of soil passes through this sieve soil is called sand and is denoted with letter S.

USCS CLASSIFICATION

- If the coarse grained soils contain less than 5% fines and are well graded (characterized by value of Cu and Cc) they are given the symbol **GW** and **SW** and if poorly graded (P) symbols **GP** and **SP**.

(GW AND SW represents that soil contain all kind of particles)



USCS CLASSIFICATION

COARSE-GRAINED SOILS
(more than 50% of material is larger than No. 200 sieve size.)

Major division	Group symbol	Description
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures

Primary Letter:

G: Gravel

S: Sand

M: Silt

C: Clay

O: Organic

P_t: Peat

Secondary Letter:

W: Well-graded

P: Poorly-graded

M: Non-plastic fines

C: Plastic fines

O: Low plasticity

H: High Plasticity

USCS CLASSIFICATION

- If the coarse grained soils contain **more than 12% fines** then

GM for gravel soil containing silt

GC if the fines are clay

SM if soil is sand and contains fines of silt

SC if sand contains fines of clays

Primary Letter:

G: Gravel

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Secondary Letter:

W: Well-graded

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USCS CLASSIFICATION

- If the coarse grained soils contain **fines between 5% and 12%**

(GW-GM) (between Well Graded gravel and Silty Gravel)

(SP-SC) (between Poorly Graded Sand and Clayey Sand)

Primary Letter:

G: Gravel

S: Sand

M: Silt

C: Clay

O: Organic

P_t: Peat

Secondary Letter:

W: Well-graded

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USCS CLASSIFICATION

Fine Grained Soil

Fine grained soils are further divided into two types:

i) Soils of **Low compressibility (L)** if the liquid limit is 50% or less (**ML, CL, OL**)

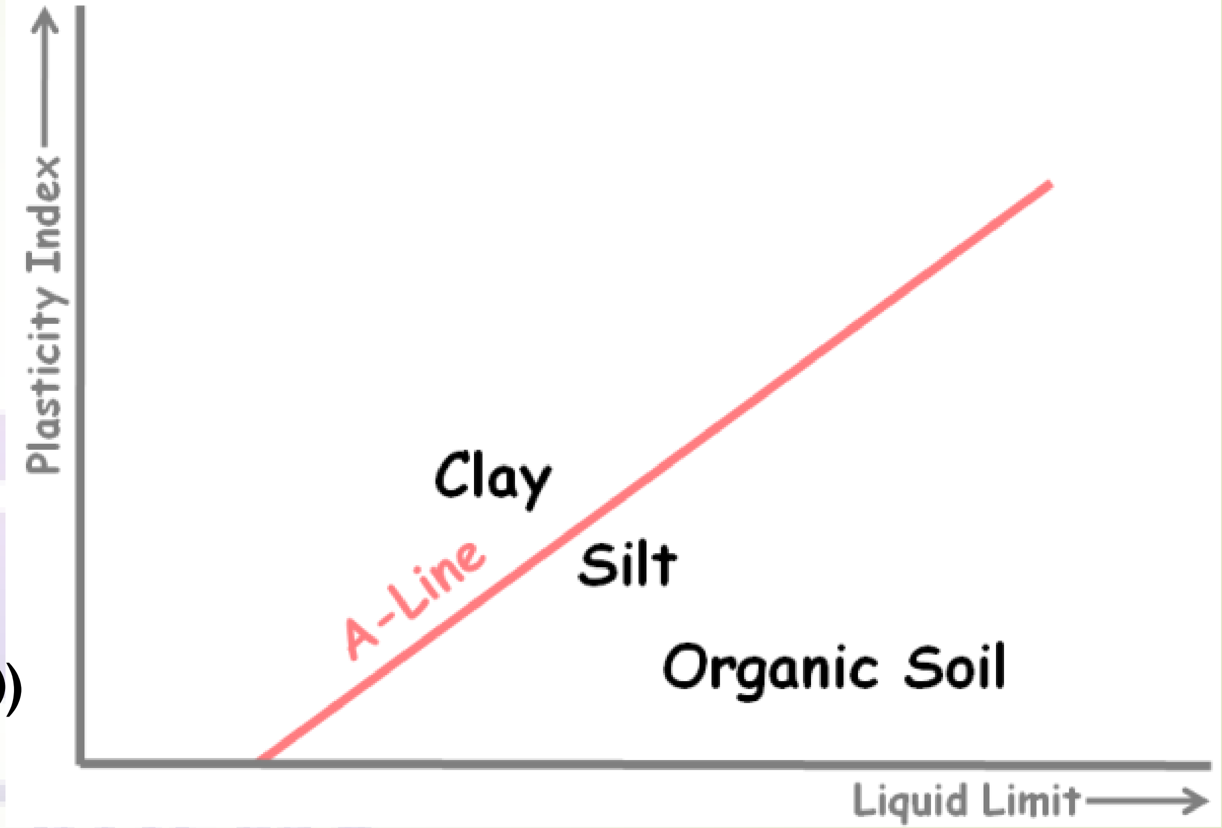
i) Soil of **High Compressibility (H)** if the liquid limit is more than 50%. **(MH, CH, OH)**

USCS CLASSIFICATION

Plasticity Chart

The exact type of soil is determined from plasticity chart.

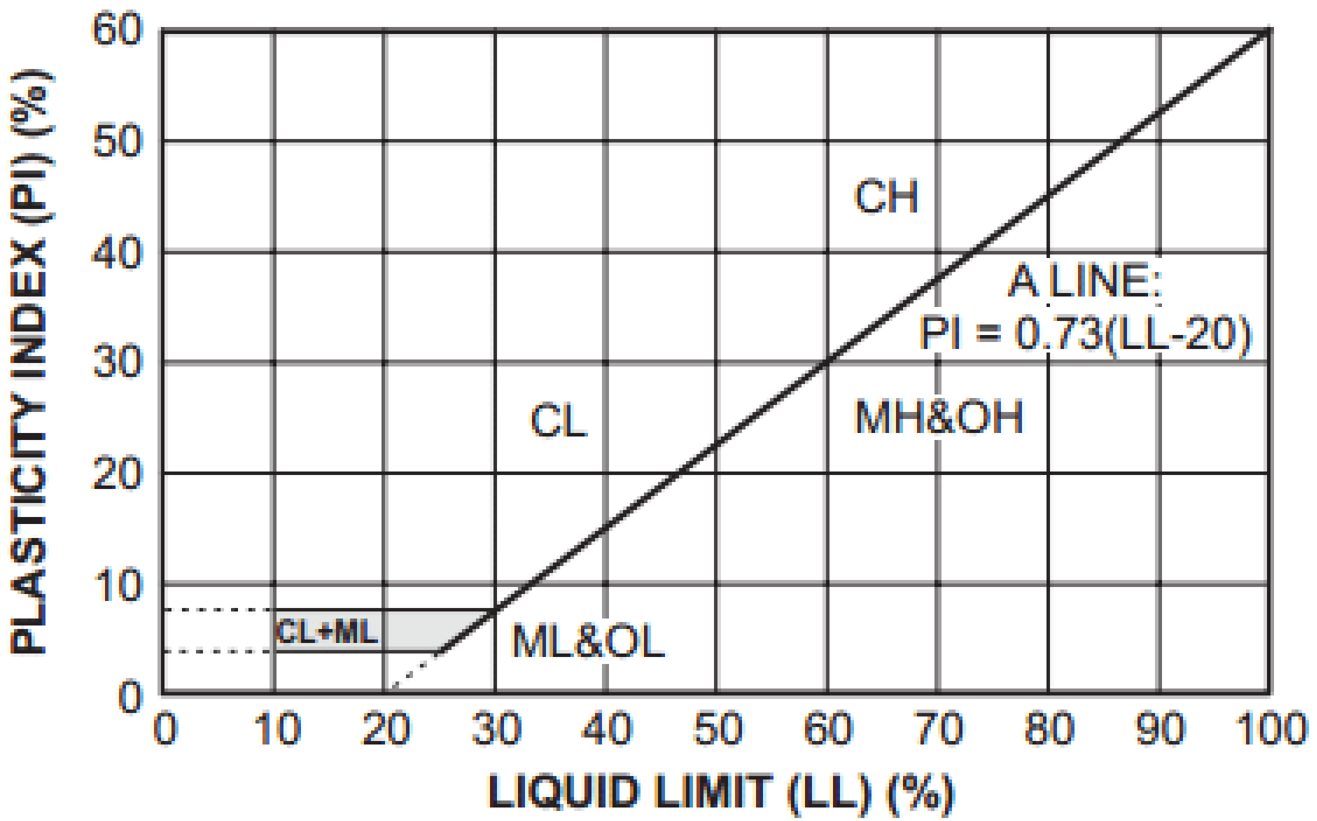
The A-line has the equation **$I_p = 0.73 (W_L - 20)$**



3.3: STANDARD SOIL CLASSIFICATION

FINE-GRAINED SOILS
(50% or more of material is smaller than No. 200 sieve size.)

SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

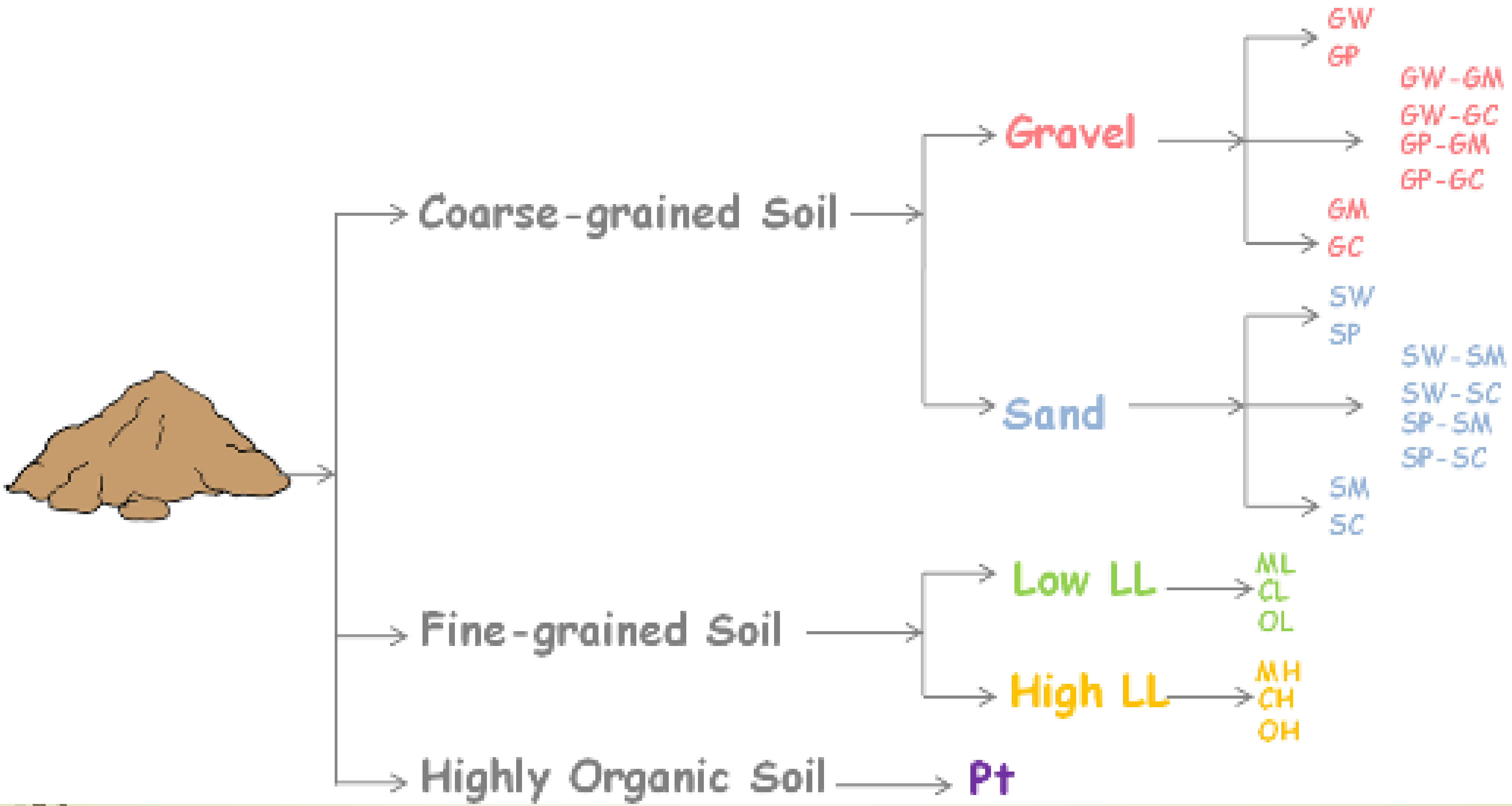


$LL_{\text{After oven-drying}} - LL_{\text{Before oven-drying}}$

=> 30% = Organic Soil = OL, OH

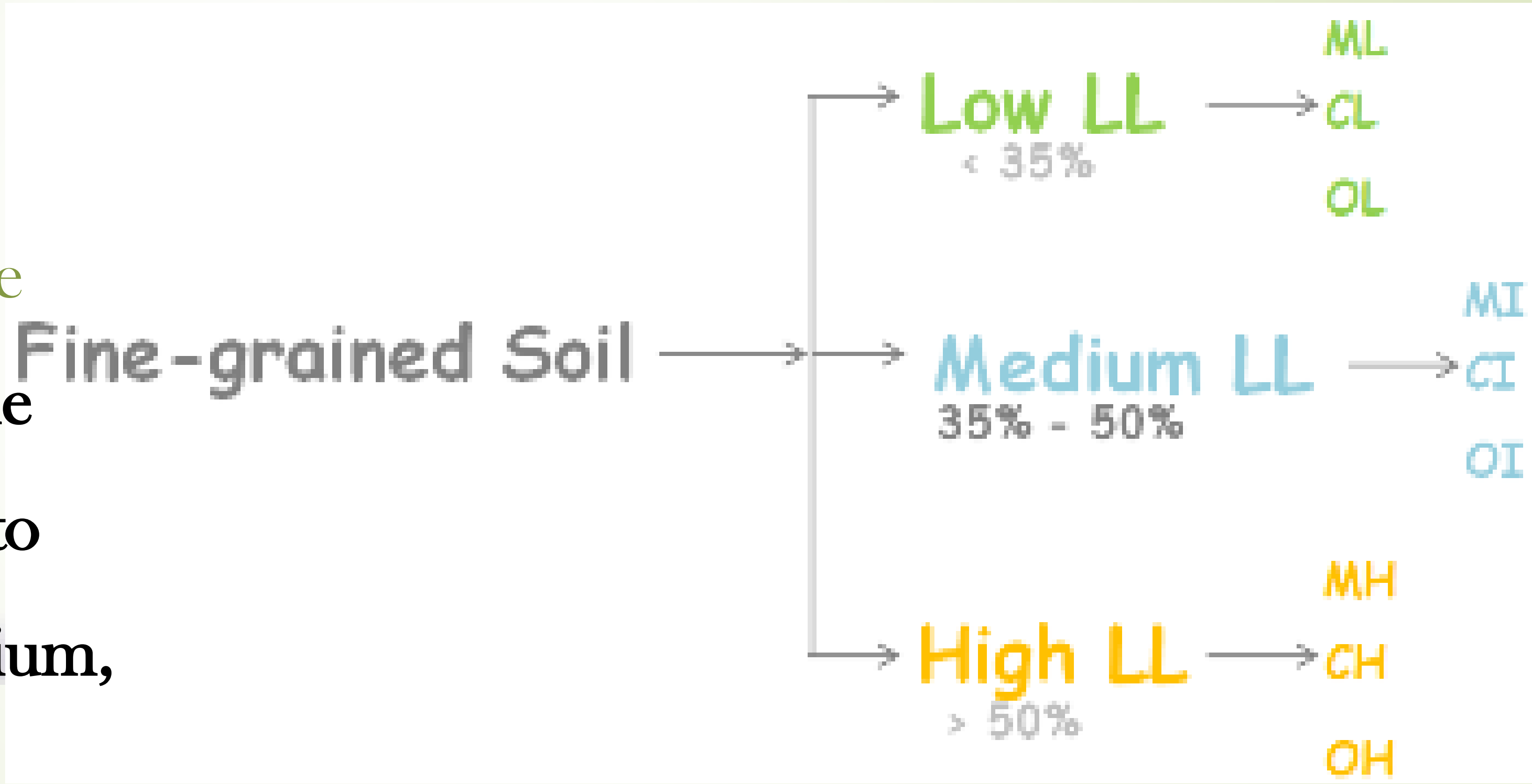
< 30% = Inorganic Soil = ML, MH

3.3: STANDARD SOIL CLASSIFICATION



ISSCS (Indian Standard Soil Classification System)

Similar to the unified soil classification system, the only difference is that in the Indian standard system, the fine grained soils are subdivided into three groups namely low, medium, and high compressibility.



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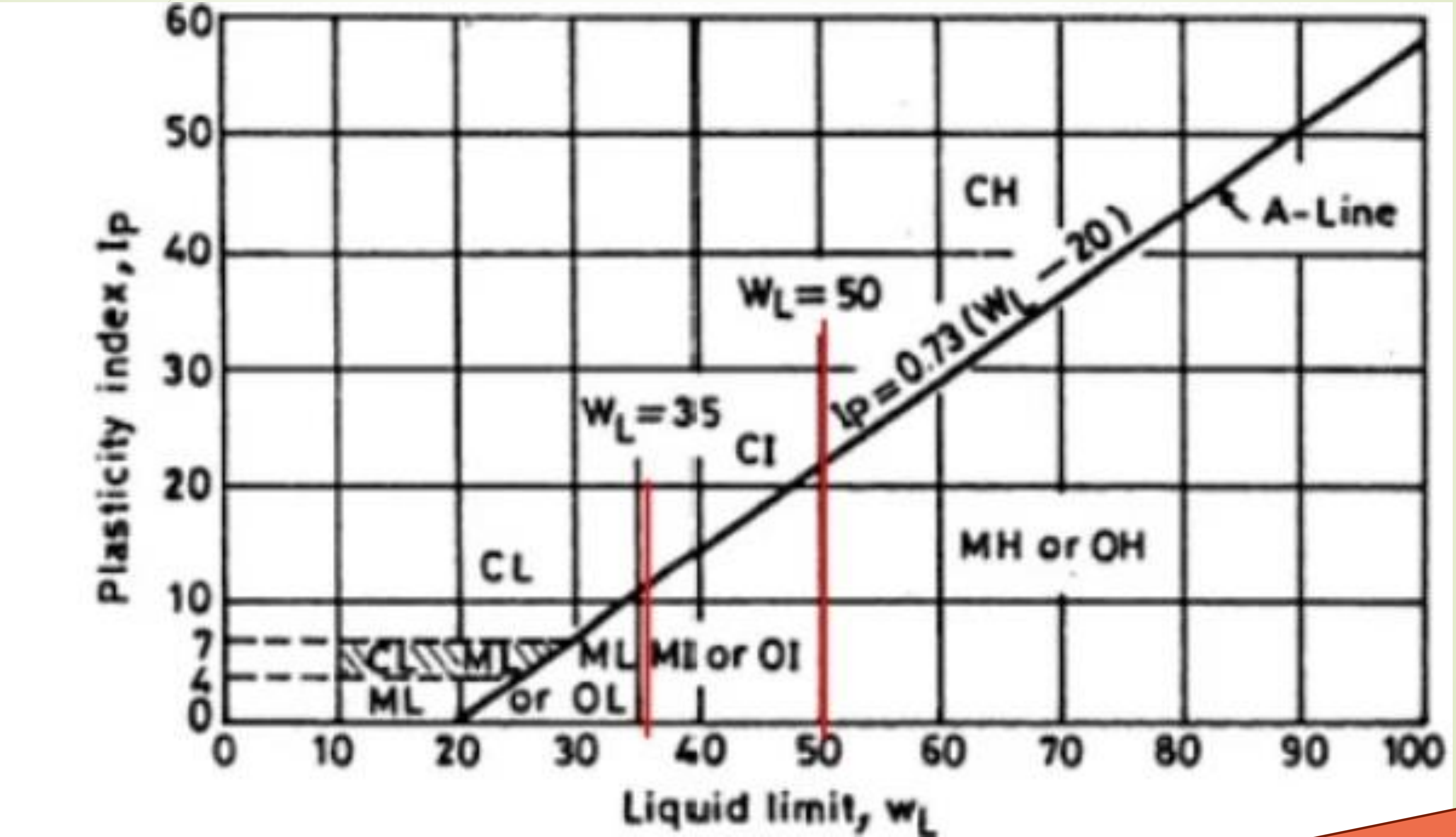


3.3: STANDARD SOIL CLASSIFICATION

DAACA

1. The soil which contains finest grain particles is:
   a. Coarse Sand
   b. Fine Sand
   c. Silt
   d. Clay
2. Minimum size of the particle of the silt soil is:
   a. 0.002 mm
   b. 0.04 mm
   c. 0.06 mm
   d. 0.08 mm
3. Maximum size of grains of silt is about:
   a. 0.06 mm
   b. 0.2mm
   c. 0.5mm
   d. 1 mm

4. What is the maximum percentage of fines in clean gravel according to USCS?
   a) 2% b)4% c)5% d) 9%

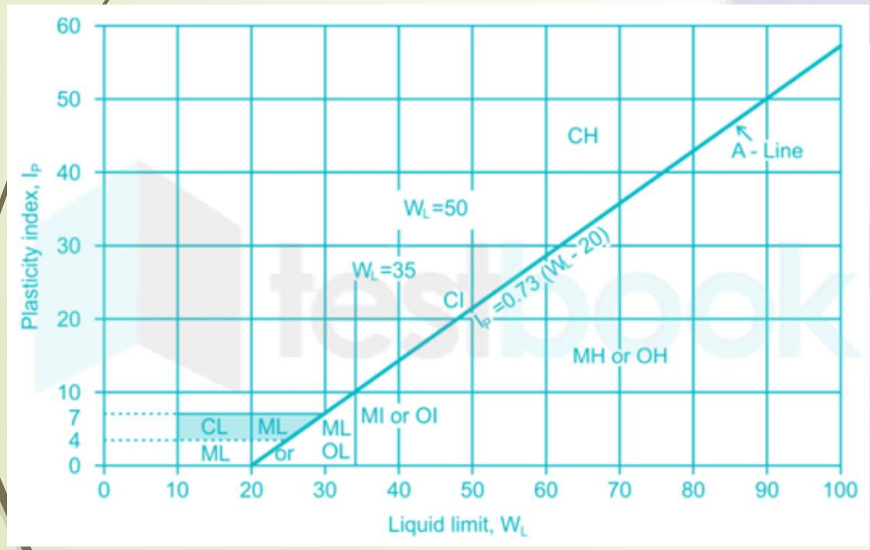
5. Soil passing through 4.75 mm sieve but retained on 75 microns sieve and also containing 7% clay is considered to be?
   a) SP-SC b) SP c) SC d) any of the above depending on coefficient of uniformity

3.3: STANDARD SOIL CLASSIFICATION

B

6. A fine grained soil has liquid limit of 60 and plastic limit of 20. As per the plasticity chart, according to IS classification, the soil represented by the letter symbols:

a) CL b) CH c) ML d)MH



Liquid limit (W_L) = 60%

Plastic limit (W_p) = 20%

I_P of soil = $W_L - W_P$ = 60 - 20 = 40%

I_P of A-line = 0.73 (W_L -20) = 0.73 (60 - 20) = 29.2%

I_P of soil > I_P of A-line, So it will lie above A-line and also W_L > 50%,

∴ **Soil is CH.**

Stresses on soil

In-situ Stress on soil mass is studied under total stress, effective stress and pore water pressure. **Total stress** at any plane in a soil mass, is the total load per unit area. Pore water pressure is the pressure due to pore water filling the voids of the soil. **Effective stress** is the difference between total stress and pore water pressure.

$$Total\ Stres\ (\sigma) = \gamma.h$$

$$Pore\ water\ pressure\ (u) = \gamma_w.h_w$$

$$Effective\ Stress\ (\sigma') = \sigma - u = \ .h - \gamma_w.h_w$$

Here, γ = bulk unit weight of the soil (taken saturated unit weight if soil is saturated and dry unit weight when soil is dry),

γ_w=unit weight of water

h=depth of the soil at which stress is being calculated.

h_w=depth from the layer at which the stress is being calculated to the water table. (**it is taken negative if lies above the water table due to capillarity action)**

For saturated soil,

$$(\sigma') = \sigma - u = \ .h - \gamma_w.h = \gamma_{sub}h$$

Effective stress or inter-granular stress is due to the external load acting on the soil and the self-weight of the soil particles. **Effective stress is transmitted through grain to grain** at point of contact through soil mass. It is effective in decreasing void ratio of mass & in mobilizing the shear strength of soil.

Factors affecting effective stress are:

- Water Table Fluctuation
  - ✓ The effective stress at any section goes on increasing as the water table goes down.
  - ✓ The effective stress depends upon the bulk unit weight above the water table and the submerged unit weight below the water table.
  - ✓ The effective stresses in a soil mass is independent of the depth of water above the soil surface. [Example, Pond]
- Surcharge
  - ✓ When the soil surface is subjected to a surcharge load of intensity q per unit area, the effective stress is increased by q throughout.

- **Capillary Action**
  - ✓ Capillary rise enables the soil to retain water and also assists in regulating flow. Pore size influence the height upto which water rises. Smaller the pores, higher will be capillary rise. As fine-grained soils have smaller pores, rise will be more in such type of soils.
  - ✓ The capillary water above a water table causes a negative pressure $\gamma_w H$, where H is the capillary rise. This negative pressure causes an increase in effective stress at all levels below the saturation level. The increase is equal to $\gamma_w H$. The capillary action is equivalent to surcharge $q = \gamma_w H$.
  - ✓ If the soil is saturated due to rise in water table, the effective stress depends upon the submerged unit weight; whereas for the soil saturated with capillarity water, the effective stress depends upon the saturated unit weight.
  - ✓ If the water table rises to the top soil surface, the meniscus is destroyed and the capillarity water changes to the free water, and the effective stress is reduced throughout.
  - ✓ Pore water pressure in the capillary zone is negative.
- Seepage condition
  - ✓ As the water flows through the soil, it exerts a seepage force on the soil particles. The seepage force affects the interparticle forces and hence the effective stress.
  - ✓ The effective stress is increased when the flow is downward, as the seepage force increases the interparticle forces.
  - ✓ When the flow is upward, the effective stress is decreased as the seepage force decrease the interparticle forces.

Quick sand condition

The effective stress is reduced due to upward flow of water. When the head causing upward flow is increased, a stage is reached where the effective stress is reduced to zero. The condition so developed is known as quick sand condition. The hydraulic gradient at which quick sand occurs is called critical hydraulic gradient (i_{cr}).

$$i_{cr} = \frac{G-1}{1+e}$$

We know,

$$\gamma_{sub} = \left(\frac{G-1}{1+e}\right) \cdot \gamma_w$$

$$Hence, i_{cr} = \frac{\gamma_{sub}}{\gamma_w} \cong 1$$

A saturated sand becomes “Quick” or “Alive” at the critical hydraulic gradient. Here, “quick sand” is not the type of sand but is only a hydraulic condition. At this condition, flow will be occurring in the upward direction under critical hydraulic gradient and soil loses all its effective stress. Shear strength of all soils is a function of effective stress. Some soil loses their strength when effective stress reduces to zero (cohesionless soil). Such condition is called quick or boiling condition which is dangerous as soil supports nothing.

$$Shear\ stress\ (\tau) = c + \sigma' \tan\phi$$

For cohesionless soil, c=0 and shear stress = 0 at quick condition.

CBBCC

DBBA

7. Quick Sand is a:
   a. Moist sand containing small particles
   b. Condition which occurs in coarse sand
   c. Condition in which a cohesionless soil loses all its strength because of upward flow of water
   d. None
8. The critical gradient of the seepage of water in a soil medium is:
   a. (1-G) / (1+e)
   b. (G-1) / (1+e)
   c. (1+e) / (1-G)
   d. (1+e) / (G-2)
9. Critical gradient of al soil is normally:
   a. 0.5
   b. 1
   c. 1.5
   d. 2
10. Neutral stress refers to:
    a. Major principal stress
    b. Minor principal stress
    c. Pore water pressure
    d. Effective stress
11. The difference between total pressure and pore water pressure is known as:
    a. Major principal stress
    b. Minor principal stress
    c. Effective stress d. None of the above
12. Effective Stress is
    a. The stress at the particles contact
    b. Governing factor for the engineering properties of the soil
    c. A physical parameter
    d. All of the above
13. Rise in water table position upto the ground surface causes
    a. Increase in effective Stress
    b. Decrease in effective stress
    c. Increase in total stress d. Decrease in total stress
14. The stress that is responsible for the mobilization of shearing strength of a soil
    a. Total stress
    b. Effective stress
    c. Neutral stress
    d. None
15. Rise of water table above the ground surface causes
    a. Equal increase in pore water pressure and total stress
    b. Equal increase in pore water pressure and effective stress
    c. Equal increase in total stress and effective stress
    d. None of the above

BAA

16. The saturated unit weight of sand in the bed of a pond 20 m deep is 20 kN/m^3. Unit weight of water is 10 kN/m^3. The effective stress at 4 m below bed level of pond is:
    a. 20 kN/m^2
    b. 40 kN/m^2
    c. 60 kN/m^2
    d. 80 kN/m^2
17. What is the effective stress at a depth of 10 m below the ground level, when water table is 3 m below ground level, saturated density is 20 kN/m^3 and bulk density is 18 kN/m^3?
    a. 124 kN/m^2
    b. 116 kN/m^2
    c. 264 kN/m^2
    d. 194 kN/m^2
18. A uniform collapsible sand stratum, 2.5 m thick, has specific gravity of its sand as 2.65, with a neutral void ratio of 0.65. The hydraulic head required to cause quick collapsible sand condition is:
    a. 2.50 m
    b. 2.75 m
    c. 3.25 m
    d. 3.50 m

PERMEABILITY

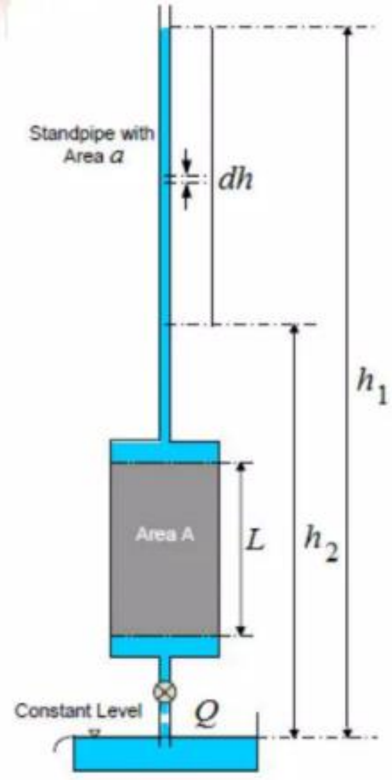
- Property of soil which enables the flow of water through it.
- Or, It is the property which describes quantitatively, the ease with which water flows through that soil.
- **DARCY LAW:**
  - In 1856, Darcy demonstrated experiment that for laminar flow in a homogenous soil, the velocity of flow (v) is given by: $\boldsymbol{v = ki}$
  - Where; k= coefficient of permeability and i= hydraulic gradient
  - $\boldsymbol{i = \frac{head\ loss}{length\ of\ flow}}$
  - $\boldsymbol{Discharge\ through\ soil\ (q) = kiA}$
  - The coefficient of permeability is defined as the velocity of flow which would occur under unit hydraulic gradient. It is the unit of length/time (mm/sec).
- Darcy law is valid if the flow through the soil is laminar. (Since pores are so small that the flow of water is almost always laminar)
- Here, $v = ki$, represents the **superficial or fictitious velocity** of flow because actual flow is through pores in the cross section and not through the entire cross section area A.
- The actual velocity of water flowing in the voids is called Seepage Velocity (v_s).

$$v_s = \frac{v}{n} = \frac{ki}{n} = \left(\frac{k}{n}\right) i = k_p . i$$

- k_p = Coefficient of percolation ; n = porosity

Falling Head Permeability Test

- Used for relatively less permeable soil (fine grained soil)



❑ Rate of flow of water through the specimen at any time 't' can be given by;

$$q = k\frac{h}{L}A = -a\frac{dh}{dt}$$

q: rate of flow

a: cross sectional area of standpipe

A: cross sectional area of the soil sample

$$dt = \frac{aL}{Ak}\left(-\frac{dh}{h}\right) \Rightarrow \int_0^{t_1} dt = -\frac{aL}{Ak}\int_{h_2}^{h_1}\frac{dh}{h}$$

$$t = \frac{aL}{Ak}\ln\frac{h_1}{h_2} \Rightarrow k = \frac{aL}{At}\ln\frac{h_1}{h_2}$$

$$\boxed{k = 2.303\frac{aL}{At}\log\frac{h_1}{h_2}}$$

h_1 = head at the start of test

h_2 = head at the end of test

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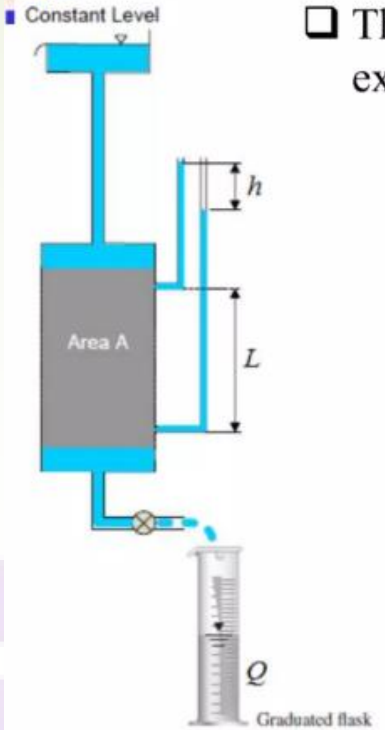

❑ The total *volume of collected water* may be expressed as;

$$Q = q \cdot t = (Av) \cdot t = A \cdot (ki) \cdot t$$

$$i = \frac{h}{L} \qquad Q = A\left(k\frac{h}{L}\right)t$$

$$\boxed{k = \frac{QL}{Aht}}$$

Q = volume of water collected

A = x-sec area of soil specimen

t = duration of water collection

Constant Head Permeability Test

- Used for relatively more permeable soil (coarse grained soil)

Factors Affecting Permeability

$$k = C\frac{\gamma_w}{\mu}\frac{e^3}{1+e}D^2$$ Hazen-Poisseuille Equation:

- Particle Size: $k \propto D^2$
- Void Ratio: $k \propto \frac{e^3}{1+e}$ (Higher void ratio, higher permeability)
  - **But**, The soil with largest void ratio (i.e., clays) are least pervious. This is because individual void passages in clays are extremely small.
- Properties of water:

$$k \propto \frac{\gamma_w}{\mu}$$

  - If temperature increases, viscosity decreases. As viscosity decreases, permeability increases. Hence, increase in temperature, increases permeability.
- Degree of saturation: (Unsaturated soil has lesser permeability)
- Presence of Adsorbed water, impurities in water in the soil reduces permeability.
- Shape of the particles:
  - For same void ratio, the **soils with angular particles are less permeable** than those with rounded particles as permeability is inversely proportional to the specific surface area (Angular particles have greater surface area)
- Structure of soil: (Permeability is higher for flocculated structure than dispersed)

Permeability higher along the stratification than perpendicular to the stratification.