GATE – CIVIL ENGINEERING

GEOTECHNICAL ENGINEERING

Department of Civil Engineering

FORMULAS – INDEX PROPERTIES

$$G = \frac{\gamma_s}{\gamma_w}$$

$$G = \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

$$G = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)} \times G_k$$

$$G = \frac{W_s.(G_w)_T}{W_s - (W_3 - W_4)}$$

$$G_{T_2} = G_{T_1}.\frac{(G_w)_{T_2}}{(G_w)_{T_1}}$$

$$V_s = \frac{g}{18}.(G-1)\frac{d^2}{\nu}$$

$$C_u = \frac{D_{60}}{D_{10}} \qquad C_c = \frac{(D_{30})^2}{D_{60}.D_{10}}$$

$$w = \frac{W_w}{W_d} \times 100 = \frac{W - W_d}{W_d} \times 100$$

$$w = \left[\frac{W_2 - W_1}{W_3 - W_4} \times \left(\frac{G-1}{G}\right) - 1\right]$$

FORMULAS – INDEX PROPERTIES

$$w=\left[\frac{W_2-W_1}{W_3-W_4}\times\left(\frac{G-1}{G}\right)-1\right]$$

$$I_D=\frac{e_{\max}-e}{e_{\max}-e_{\min}}\times 100$$

$$S_r=\frac{V_1-V_2}{V_1}\times 100$$

$$I_D=\frac{\gamma_{d\ \max}}{\gamma_d}\left[\frac{\gamma_d-\gamma_{d\min}}{\gamma_{d\max}-\gamma_{d\min}}\right]$$

$$e_{\max}=\frac{V_{v\max}}{V_{s\min}}$$

$$e=\frac{G.\gamma_w}{\gamma_d}-1$$

$$e_{\min}=\frac{V_{v\min}}{V_{s\max}}$$

$$I_f=\frac{(w_2-w_1)}{\log_{10}\left(\frac{N_1}{N_2}\right)}$$

$$w_s=\frac{(W_i-W_d)-(V_i-V_m)\gamma_w}{W_d}\times 100$$

$$w_s=\frac{1+e}{G}-\frac{1}{G}=\frac{e}{G}$$

$$SR=\frac{\left[\frac{V_i-V_d}{V_d}\times 100\right]}{(w_i-w_s)}$$

$$V_s=\frac{V_i-V_d}{V_d}\times 100=SR(w_i-w_s)$$

$$S_t=\frac{q_u(\text{Undistrubed})}{q_u(\text{Remoulded})}$$

$$I_P=LL-PL$$

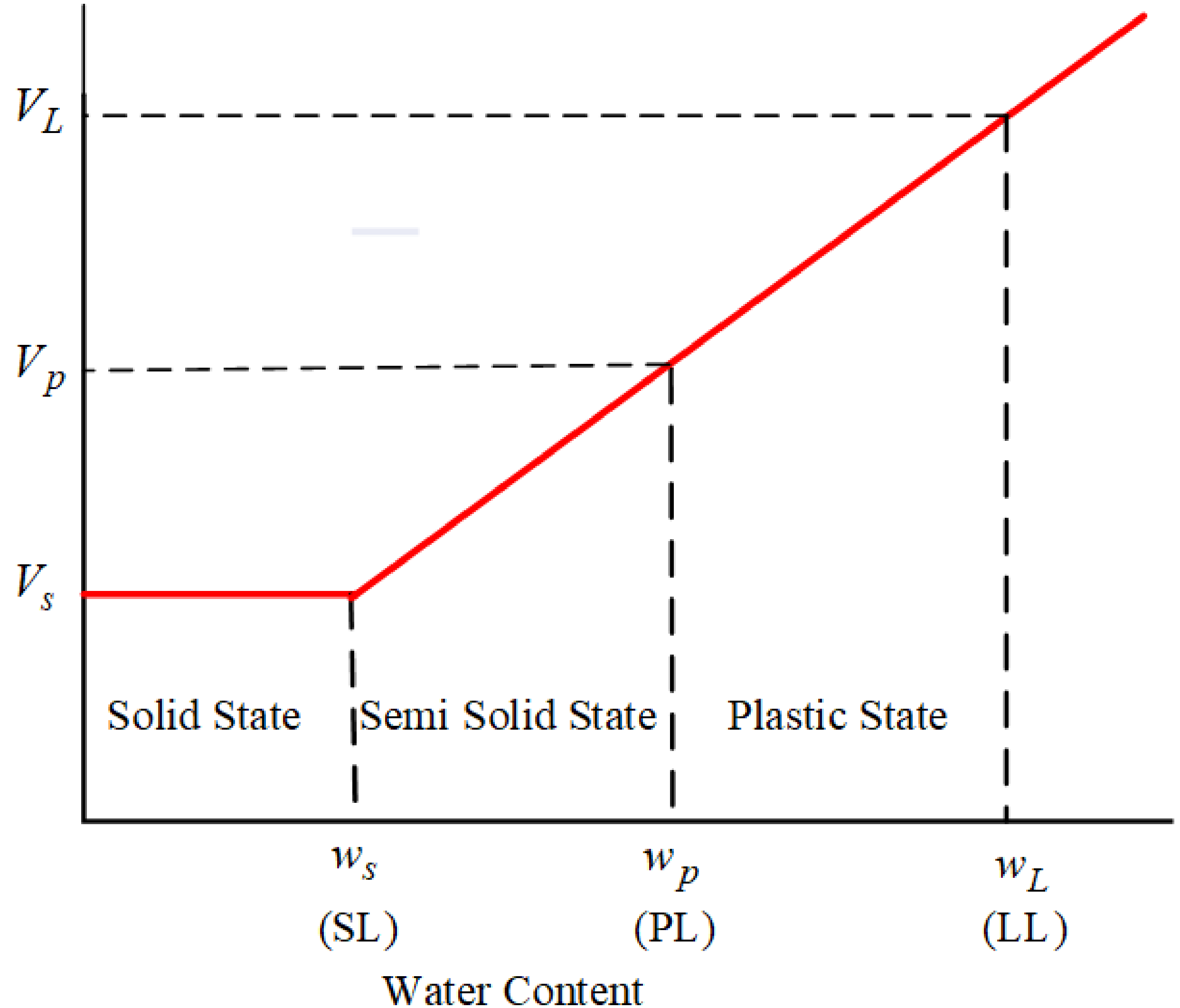
$$I_L=\frac{w-PL}{PI}=\frac{w-w_p}{I_p}$$

$$I_S=PL-SL$$

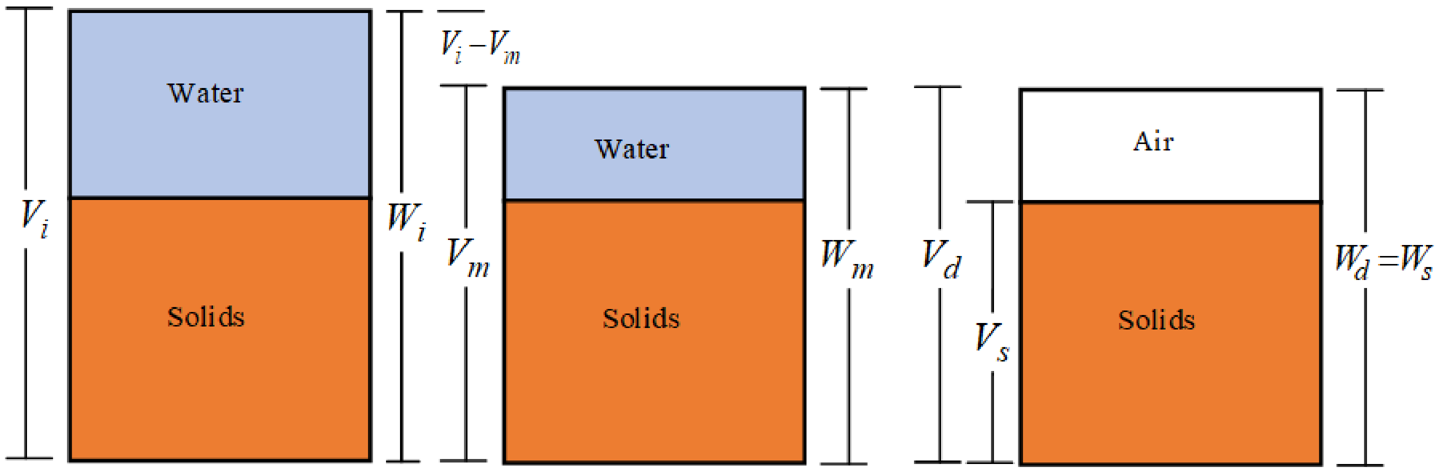
$$I_C=\frac{LL-w}{PI}=\frac{w_L-w}{I_p}$$

$$I_T=\frac{I_P}{I_f}$$

$$A=\frac{I_P}{C}$$



Different States of Soil



Soil pat at initial stage

$$w_s = \frac{(W_i - W_d) - (V_i - V_m)\gamma_w}{W_d} \times 100$$

$$w_s = \left[w_i - \frac{(V_i - V_d)\gamma_w}{W_d} \right] 100$$

$$w_s = \frac{(V_d - V_s)\gamma_w}{W_d} \times 100 = \left[\frac{\gamma_w}{\gamma_d} - \frac{1}{G} \right] \times 100 \qquad \gamma_d = \frac{G.\gamma_w}{1+e} \qquad w_s = \frac{1+e}{G} - \frac{1}{G} = \frac{e}{G}$$

8.3 Index Properties of soil (Numerical Questions)

1. An oven dried sample has a weight of 165 g is kept inside a pycnometer and then filled completely with water. The weight of pycnometer with soil and water is found to be 1552 g and the weight of pycnometer filled with water alone is 1448 g. The specific gravity of soil solids is

a. 2.56 b. 2.60 c. 2.65 **d.** 2.7

Ans. d

$$\text{Specific gravity}\, G = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$$

Weight of over dried sample, $W_d = W_2 - W_1 = 165\text{g}$

Weight of pyknometer + sample + water, $W_3 = 1552\text{g}$

Weight of pyknometer + water, $W_4 = 1448\text{g}$

$$G = \frac{165}{165 - (1552 - 1448)} = 2.70$$

2. Following observations were made to determine the specific gravity of soil solids using density bottle method.

Weight of density bottle = 84 g

Weight of bottle + soil = 126 g

Weight of bottle + soil + kerosene = 288 g

Weight of bottle + kerosene = 258 g

Specific gravity of kerosene = 0.773.

The specific gravity of soil solids is

a. 2.62 b. 2.67 **c.** 2.71 d. 2.82

Ans. c

Specific gravity of soil, $G = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)} . G_K$

$W_1 = 84\text{g}$ $W_2 = 126\,\text{g}$ $W_3 = 288\text{g}$ $W_4 = 258\text{g}$ $G_k = 0.773$

$$G = \frac{126 - 84}{(126 - 84) - (288 - 259)} \times 0.773 = 2.71$$

3. The following observations were made in determining the water content of a soil sample by pycnometer method weight of pycnometer, W_1 = 924 g
Weight of pycnometer + wet sample, W_2 = 1169 g
Weight of pycnometer + soil + water, W_3 = 2172 g
Weight of pycnometer + water, W_4 = 2048 g
If the specific gravity of soil solids is 2.69, then the water content of the soil sample is

a. 0 b. 12.3% **c.** 24.4% d. 50.6%

Ans. C

Water content, $$w = \left[\frac{W_2 - W_1}{W_3 - W_4}\left(\frac{G-1}{G}\right) - 1\right]$$

$$= \left[\left(\frac{1169 - 924}{2172 - 2048}\right)\left(\frac{2.69 - 1}{2.69}\right) - 1\right] = 0.244 = 24.4\%$$

4. The weight and volume of a saturated clay specimen were 38 g and 21 cm^3 respectively. On oven drying, the weight got reduced to 24 g and the volume to 10 cm^3. The shrinkage limit of the soil is

a. 12.5% b. 13.53% c. 52.4% d. 58.3%

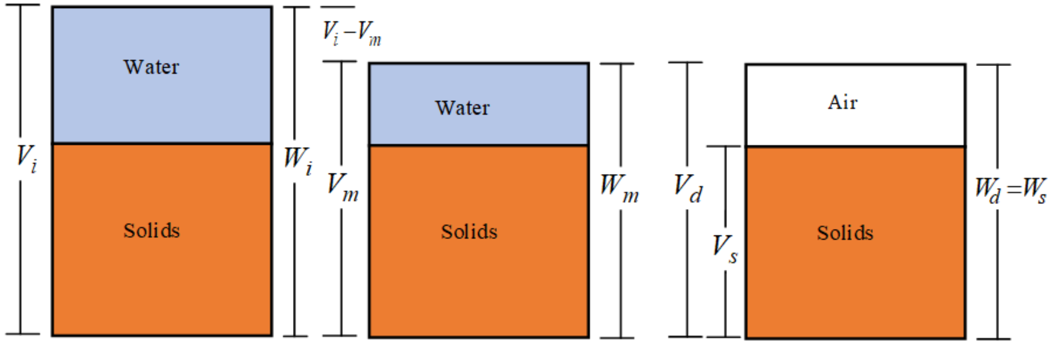
Ans. a

Weight of wet soil specimen, W_i = 38 g

Volume of wet soil specimen, V_i = 21 cm^3.

Weight of dry soil specimen, W_d = 24 g

Volume of dry soil specimen, V_d = 10 cm^3.



Soil pat at initial stage

$$\text{Shrinkage limit, } w_s = \frac{(W_i - W_d) - (V_i - V_d)\gamma_w}{W_d} \times 100$$

$$= \frac{(38-24)-(21-10)\times 10}{24} \times 100 = 0.125 = 12.5\%$$

5. An oven dried sample has a weight of 172 g was kept inside a pycnometer and then filled completely with water. The weight of pycnometer with soil and water is 1568 g and the weight of pycnometer filled completely with water is 1461 g. Later it was found that while finding the weight of pycnometer with soil and water, 2 cm^3 of air got entrapped. The correct specific gravity is

a. 2.62 b. 2.65 c. 2.70 **d.** 2.73

Ans. d

Specific gravity, $G = \dfrac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$

$W_2 - W_1 = W_d = 172\text{g}$

$W_3 = 1568$ g, $W_4 = 1461$ g

$$G = \frac{172}{172 - (1568 - 1461)} = 2.65$$

While finding W_3, 2 cm^3 of air got entrapped. Therefore W_3 is less than that when water replaces the entrapped air.

Correct $W_3 = 1568 + 2 = 1570$ g.

$$\therefore \text{Correct } G = \frac{172}{172-(1570-1461)} = 2.73$$

6. The following observations were made to determine the shrinkage limit of soil.

Weight of wet soil specimen, W_i = 30 g

Volume of wet soil specimen, V_i = 18.5 cm^3.

Weight of dry soil specimen, W_d = 18 g

Volume of dry soil specimen, V_d = 9.5 cm^3.

The specific gravity of soil sample is

a. 2.64 b. 2.70 **c.** 2.77 d. 2.82

Ans. c

Specific gravity of soil solids is given by

$$W_s = \left(\frac{\gamma_w}{\gamma_d} - \frac{1}{G}\right) \times 100$$

$$W_s : \text{Shrinkage limit} = \frac{\text{Weight of water at shrinkage limit}}{\text{Weight of soil solids}}$$

,

$$= \frac{(W_1 - W_d) - (V_i - V_d) \times \gamma_w}{W_d}$$

$$W_s = \frac{(30 - 18) - (18.5 - 9.5)}{18} = 0.167 = 16.7\%$$

$$16.7 = \left(\frac{9.5 \times 1}{18} - \frac{1}{G} \right) \times 100, \quad G = 2.77$$

8. The mass specific gravity and water content of a fully saturated soil sample was found to be 1.88 and 36% respectively. The mass specific gravity of oven dried sample is 1.80. The shrinkage limit of soil is

a. 18% **b.** 19.2% c. 24% d. 36%

Ans. b

Degree of saturation, $S = 100\%$

Mass specific gravity of wet soil, $G_m = 1.88$

Water content, w = 36%

Mass specific gravity oven dried samples

Water content, w = 36%

Mass specific gravity oven dried samples $G_{md} = 1.80$

For fully saturated soil sample, $e = wG$

$$e = 0.36G$$

$$G_m = \frac{\gamma}{\gamma_w} = \left(\frac{G+e}{1+e}\right)\gamma_w \cdot \frac{1}{\gamma_w} = \frac{\mathrm{G}+\mathrm{e}}{1+\mathrm{e}}$$

$$1.88 = \frac{G + 0.36G}{1 + 0.36G}$$

$$G = 2.75$$

Shrinkage limit, $w_s = \left(\frac{\gamma_w}{\gamma_d} - \frac{1}{G}\right) \times 100 = \left(\frac{1}{G_{md}} - \frac{1}{G}\right) \times 100$

$$= \left(\frac{1}{1.80} - \frac{1}{2.75}\right) \times 100 = 19.2\%$$

9. The liquid limit and shrinkage limit of a soil sample are 46% and 13% respectively. On over drying, the volume of soil specimen decreases from 35 cm^3 at liquid limit to 21 cm^3 at shrinkage limit. The specific gravity of soil particle is

a. 2.68 b. 2.70 b. 2.72 **d.** 274

Ans. d

Liquid limit, $w_L = 46\%$

Shrinkage limit, $w_S = 18\%$

Volume of specimen at liquid limit, $V_L = 35$ cm^3.

Volume of specimen at shrinkage limit, $V_d = 21$ cm^3.

$$\text{Shrinkage ratio, } SR = \frac{\frac{V_L - V_d}{V_d} \times 100}{w_L - w_S}$$

$$SR = \frac{\dfrac{35-21}{\Box 21}\times 100}{46-13} = 2.02$$

$$SR = \frac{\gamma_d}{\gamma_w}$$

$$w_s = \left(\frac{\gamma_w}{\gamma_d} - \frac{1}{G}\right)\times 100$$

$$13 = \left(\frac{1}{2.02} - \frac{1}{G}\right)100$$

$$G = 2.74$$

10. The liquid limit and plastic limit of a soil are 36% and 28% respectively. When the soil is dried from its state of liquid limit to dry state, the reduction in volume was found to be 35% of its volume at liquid limit. The corresponding volume reduction from the state of plastic limit to dry state was 25% of its volume at Plastic limit. The shrinkage limit of soil is

a. 14.5% b. 12.5% c. 10% d. 8%

Ans. a

Liquid limit, $w_L = 36\%$

Plastic limit, $w_P = 28\%$

V_L : Volume of soil at liquid limit

V_P : volume of soil at plastic limit

$$V_d = V_L - 0.35V_L = 0.65V_L$$

Also $V_d = V_P - 0.25V_P = 0.75V_P$

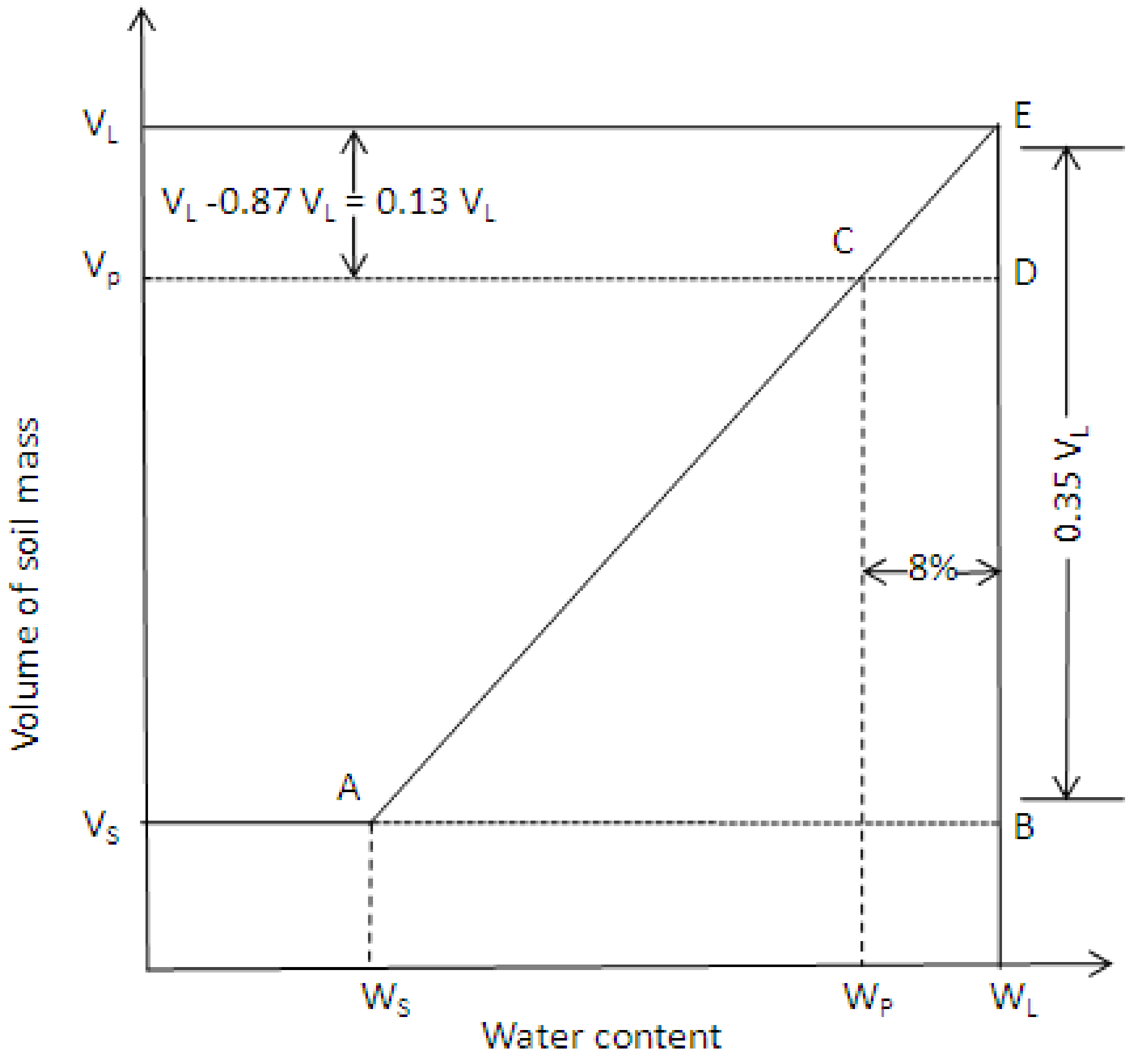
$$V_P = \frac{0.65}{0.75} V_L = 0.87 V_L$$

Shrinkage limit, $w_S = w_L - AB$

$$\frac{AB}{CD} = \frac{BE}{DE}$$

$$AB = \frac{0.35 V_L}{0.13 V_L} \times 0.08 = 0.215$$

$$w_s = 36 - 21.5 = 14.5\%$$



11. The maximum and minimum dry densities of a soil sample were found to be 18 kN/m^3 and 14 kN/m^3 respectively. The natural dry density of soil deposit is 16 kN/m^3. The density index of the soil deposit is

a. 62.5 % **b.** 56.3% c. 50% d. 28.6%

Ans. b

$$\gamma_d = 16\,kN/m^3$$

$$\gamma_{d_{max}} = 18\,kN/m3$$

$$\gamma_{d_{min}} = 14\,kN/m3$$

Density Index, $I_D = \left[\dfrac{\gamma_d - \gamma_{d\,min}}{\gamma_{d\,max} - \gamma_d}\right]\dfrac{\gamma_{d\,max}}{\gamma_d} = \left[\dfrac{16-14}{18-14}\right] \times \dfrac{18}{16} = 0.563 = 56.3\%$

12. The weight of oven dried clay pat is 0.12 N and its volume is determined by immersion in mercury and the weight of displaced mercury is 0.82 N. If the specific gravity of soil solids is 2.65, the shrinkage limit of clay is

a.10% **b.** 12.5% c. 25% d. 37.5%

Sol:

Weight of oven dried clay pat = 0.12N

Weight of displaced mercury = 0.82N

Specific Gravity of the soil = 2.65

Specific Gravity of mercury = 13.6

$$\text{Volume of mercury displaced} = \frac{0.82 \times 100}{13.6} = 603\text{cm}^3$$

$$\text{Shrinkage limit } w_s = \frac{(W_w)_{sat}}{W_d} = \frac{(V_d - V_s)\gamma_w}{W_d} = \left(\frac{\gamma_w}{\gamma_d} - \frac{1}{G}\right) = \left(\frac{1}{1.99} - \frac{1}{2.65}\right) \times 100$$

$$w_s = 12.5\%$$

8.3 Index Properties of soil Previous GATE Questions

01. The Atterberg limits of a clay are 38%, 27% and 24.5%. Its natural water content is 30%. The clay is in……….. state. GATE CE 1994

Ans. Plastic

Explanation:

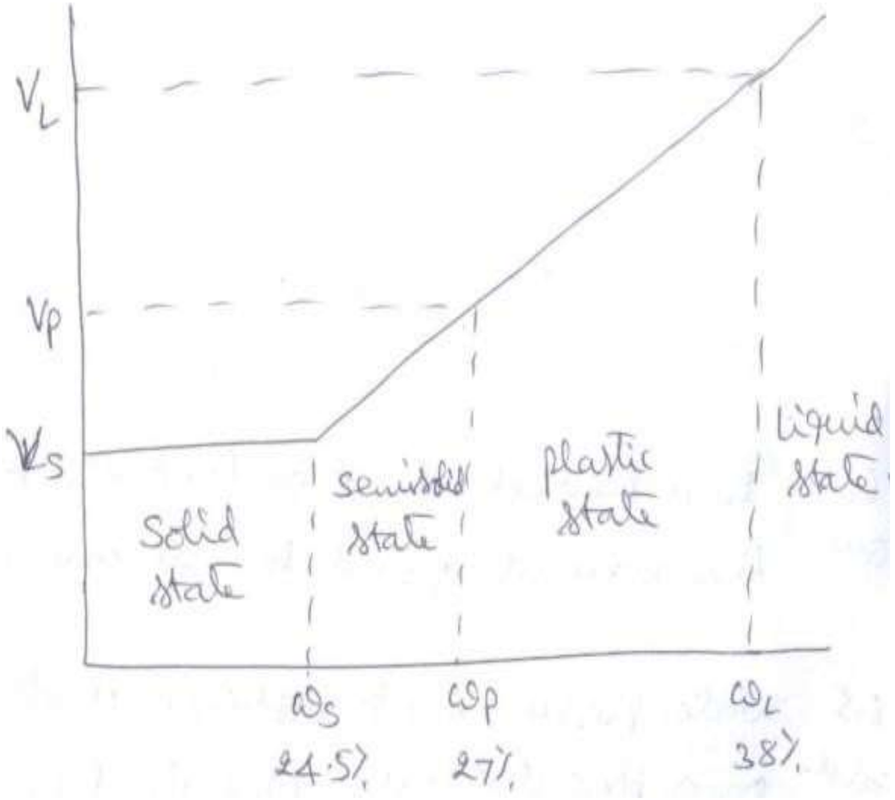
The Atterberg limits of clay:

Liquid limit, $w_L = 38\%$

Plastic limit, $w_P = 27\%$

Shrinkage limit, $w_S = 24.5\%$

Natural water content, $w = 30\%$



The natural water content of **30%** falls then the clay is in **plastic state**.

02. The consistency of a saturated cohesive soil is affected by GATE CE 1995

a. water content b. particle size distribution

c. density index d. coefficient of permeability

02. A

Explanation:

The term consistency is used to describe the degree of fineness of soil in a qualitative manner by using descriptions such as soft, medium, firm, stiff or hard. It indicates the relative ease with which a soil can be deformed. The consistency of clay is considerably influenced by the amount of water present in them.

03. Consistency Index for a clayey soil is [LL : Liquid Limit, PL: Plastic limit, PI : Plasticity index, w – natural moisture content] GATE CE 1997

a. $\frac{LL - w}{PI}$ b. $\frac{w - PL}{PI}$ c. $LL - PL$ d. $0.5w$

Ans. A

Explanation:

Consistency Index, $= \frac{LL - w}{PI}$

04. The ratio of unconfined compressive strength of an undisturbed sample of soil to that of a remoulded sample, at the same water content, is known as

GATE CE 1997

a. activity b. damping c. plasticity **d.** sensitivity

Ans. d

Explanation:

Sensitivity, $S = \dfrac{\text{Unconfined compressive strength of undistrubed soil}}{\text{Unconfined compressive strength of remounded soil}}$

$$S = \frac{q_u\,(\text{Undistrubed})}{q_u\,(\text{Remoulded})}$$

05. Some of the structural strength of a clayey material that is lost by remoulding is slowly recovered with time. This property of soils to undergo an isothermal gel-to sol-to-gel transformation upon agitation and subsequent rest is termed 1998

a. Isotropy b. Anisotropy **c.** Thixotropy d. Allotropy

Ans. c

Explanation:

Isotropy is one of the charecterstic of certain solids by which the properties measured has the **same value in all directions**. eg. Amorphous solids (Glass, Powder)

Anisotropy is one of the charecterstic of solids by virtue of which the properties such as refractive index, viscosity, etc measured **does not** have the **same value** in all the directions.

Thixotropy: When clays with a flocculent structure are used in construction, these may lose some strength as a result of **remoulding**. With passage of time the strength increases, though not back to the original value. This phenomenon of **strength loss-strength gain**, with **no change in volume or water content**, is called ‘Thixotropy’.

Allotropy or allotropism is the property possessed by certain elements to exist in two or more distinct forms that are chemically identical but have different physical properties.

06. If soil is dried beyond its shrinkage limit, it will show GATE CE 1998

a. Large volume change b. Moderate volume change

c. Low volume change **d.** No volume change

Ans. D

Explanation:

The volume of soil **decreases with a decrease in water content** till **shrinkage limit** is reached and further reduction of water content does not cause any reduction in the volume of the soil ie., no change in volume of soil.

07. The values of liquid limit and plasticity index for soils having common geological origin in a restricted locality usually define GATE CE 1999

a. a zone above line

b. a straight line parallel to Aline

c. a straight line perpendicular to Aline

d. points may be anywhere in the plasticity chart

Ans. B

Explanation:

For a common geological origin in a restricted locality, the plot based on the liquid limit and plasticity index values is a straight line parallel to A-line.

08. The toughness index of clayey soils is given by GATE CE1999

a. Plasticity index/Flow index

b. Liquid limit/Plastic limit

c. Liquidity index/Plastic limit

d. Plastic limit/Liquidity index

Ans. A

Explanation:

Toughness index of a soil is defined as the ratio of plasticity index to flowIndex

09. The void ratios at the densest, loosest and the natural states of a sand deposit are 0.2, 0.6 and 0.4, respectively. The relative density of the deposit is GATE CE 2002

a. 100% b. 75% c. 50% d. 25%

Ans. c

Solution:

Minimum void ratio or void ratio in dense state, $e_{min} = 0.2$

Maximum void ratio or void ratio in loose state, $e_{max} = 0.6$

Natural void ratio, $e = 0.4$

Relative density of soil, $I_D = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100 = \frac{0.6 - 0.4}{0.6 - 0.2} \times 100 = 50\%$

$$I_D = 50\%$$

10. The following data were obtained from a liquid limit test conducted on a soil sample.

GATE CE 2002

Number of blows	17	22	25	28	34
Water content (%)	63.8	63.1	61.9	60.6	60.5

The liquid limit of the soil is

a. 63.1% b. 62.8% c. 61.9% d. 60.6%

Ans. c

Explanation:

Number of blows	17	22	**25**	28	34
Water content (%)	63.8	63.1	**61.9**	60.6	60.5

Liquid limit is the water content corresponding to 25 blows.

Therefore, liquid limit, $w_L = 61.9\%$

11. A given cohesionless soil has $e_{max} = 0.85$ and $e_{min} = 0.5$. In the field, the soil is compacted to a mass density of 1800 kg/m^3 at a water content of 8%. Take the mass density of water as 1000 kg/m^3 and $G_s = 2.7$. The relative density (in %) of the soil is

GATE CE1 2014

a. 56.43 b. 60.25 c. 62.87 **d.** 65.41

Ans. d

Solution:

Maximum void ratio, $e_{max} = 0.85$

Minimum void ratio, $e_{min} = 0.5$

Mass density of the soil, $\gamma = 1800\,\text{kg/m}^3$

Water content, $w = 8\%$

Mass density of water, $\gamma_w = 1000\,\text{kg/m}^3$

Specific gravity of soil solids, $G_s = 2.7$

Relative density of soil, $I_D = ?$

$$\gamma = \gamma_d .(1+w) = \frac{G.\gamma_w}{1+e}.(1+w)$$

$$1800 = \frac{2.7\times 1000}{1+e}(1+0.08)$$

$$\boxed{e = 0.62}$$

$$I_D = \frac{e_{\max} - e}{e_{\max} - e_{\min}} \times 100 = \frac{0.85 - 0.62}{0.85 - 0.5} \times 100 = 65.71\%$$

12. A fine-grained soil has 60% (by weight) silt content. The soil behaves as semi-solid when water content is between 15% and 28%. The soil behaves fluid-like when the water content is more than 40%. The 'Activity' of the soil is GATE CE1 2015

a. 3.33 b. 0.42 **c.** 0.30 d. 0.20

Ans. c

Solution:

Silt content = 60%

Soil behaves as semi-solid when $w = 15\%$ to 28%

Soil behaves fluid like when $w > 40\%$

Liquid limit, $w_L = 40\%$

Plastic limit, $w_p = 28\%$

Plasticity index, $I_p = w_L - w_P = 40 - 28 = 12\%$

% finer than silt, $C = 100 - 60 = 40\%$

Activity, $A = \frac{I_P}{C} = \frac{12}{40} = 0.3$

13.The laboratory tests on a soil sample yields the following results, natural moisture content = 18%, Liquid limit = 60%, Plastic limit = 25%, Percentage of clay sized fraction = 25%. The liquidity index and activity (as per the expression proposed by Skempton) of the soil, respectively, are GATE CE1 2017

a. -0.2 and 1.4 b. 0.2 and 1.4 c. -1.2 and 0.714 d. 1.2 and 0.714

Ans. a

Solution:

Natural moisture content, $w = 18\%$

Liquid limit, $w_L = 60\%$

Plastic limit, $w_P = 25\%$

Percentage of clay sized fraction, $C = 25\%$

Liquidity index, $I_L = \dfrac{w - w_p}{I_p} = \dfrac{18-25}{60-25} = \dfrac{-7}{35} = -\dfrac{1}{5} = -0.2$

Activity, $A = \dfrac{I_p}{C} = \dfrac{60-25}{25} = \dfrac{35}{25} = 1.4$

14. In a shrinkage limit test, the volume and mass of a dry soil pat are found to be 50 cm^3 and 88 g, respectively. The specific gravity of the soil solids is 2.71 and the density of water is 1 g/cc. The shrinkage limit (in %, up to two decimal places) is….

GATE CE1 2018

Ans. 19.92

Solution:

Volume of dry soil pat, $V = 50\, cm^3$

Mass of dry soil pat, $W_d = 88 g$

Specific gravity of soil solids, $G = 2.71$

Density of water, $\gamma_w = 1 g / cc$

Dry density of soil, $\gamma_d = \frac{W_d}{V} = \frac{88}{50}$

$$\gamma_d = \frac{G\gamma_w}{1+e} \Rightarrow \frac{88}{50} = \frac{2.71\times1}{1+e} \Rightarrow e = 0.5398$$

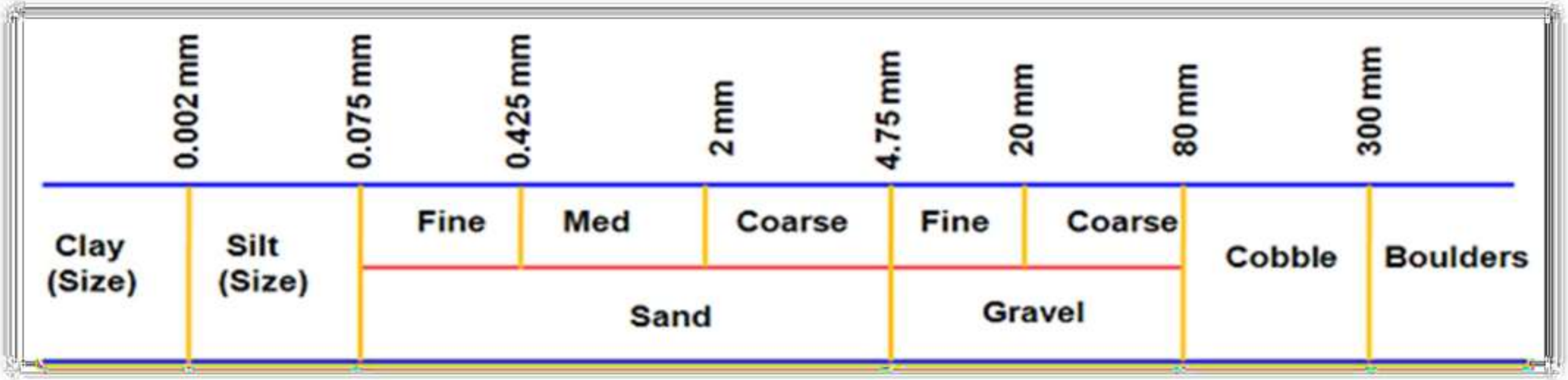
Shrinkage limit, $w_s = \frac{e}{G} = \frac{0.5398}{2.71} = 0.1992 = 19.92\%$

8.4 Soil Classification

8.4 Soil Classification

Soil Classification is done based on "Index Properties".
Classification is done based on grain size only.
Soil is classified based on grain size clay, silt, sand, gravel, cobble, and boulder.

I.S. Particle size classification:



- Derived from unified soil classification system.
- Soil classification is Based on i. grain size distribution ii. Plasticity characteristics iii. Compressibility

- Organic and Inorganic soils are distinguished by odour test, colour test, liquid limit after oven drying.

Colour Test: Organic soils have a colour of dark grey.

Odour Test: Organic soil has odour similar to that of decaying organic matter.

Liquid Limit test: The Liquid Limit of oven dried organic soils will get reduced to less than 75% of the original liquid limit before oven drying (i.e. decreases by more than 25%) of the initial value.

Soils are classified into three categories

1. Coarse grained soils: More than 50% of the soil is larger then 75μ size

   a. Gravels (G): More than 50% of coarse fraction (+75μ) is larger than 4.75 mm size

   b. Sands (S): More than 50% of coarse fraction (+75μ) is smaller than 4.75 mm size

2. Fine grained soils: More than 50% of the soil is smaller than 75μ size.

a. Silts (M) and clays (C) of low compressibility (L) LL<35%

b. Silts (M) and clays (C) of medium compressibility (I) 35% < LL < 50%

c. Silts (M) and clays (C) of high compressibility (H) LL > 50%

3. Highly organic soils (O)

Plasticity Chart:

- Fine grained soils are classified based on plasticity characteristics.
- It is developed by Casagrande.
- The equation of A line is $I_P = 0.73(w_L - 20)$
- It gives height of A line above X-axis.
- A-line stands for A Casagrande.
- The values of liquid limit and plasticity index for soils having common geological origin in a restricted locality usually defined a straight line parallel to A- line.

- Inorganic clays are plotted above A-line

  CL : Low compressible inorganic clay

  CI : Intermediate compressible inorganic clay

  CH : High compressible inorganic clay

- Inorganic silts are plotted below A-line.

  ML: Low compressible inorganic silt

  MI : Intermediate compressible inorganic silt

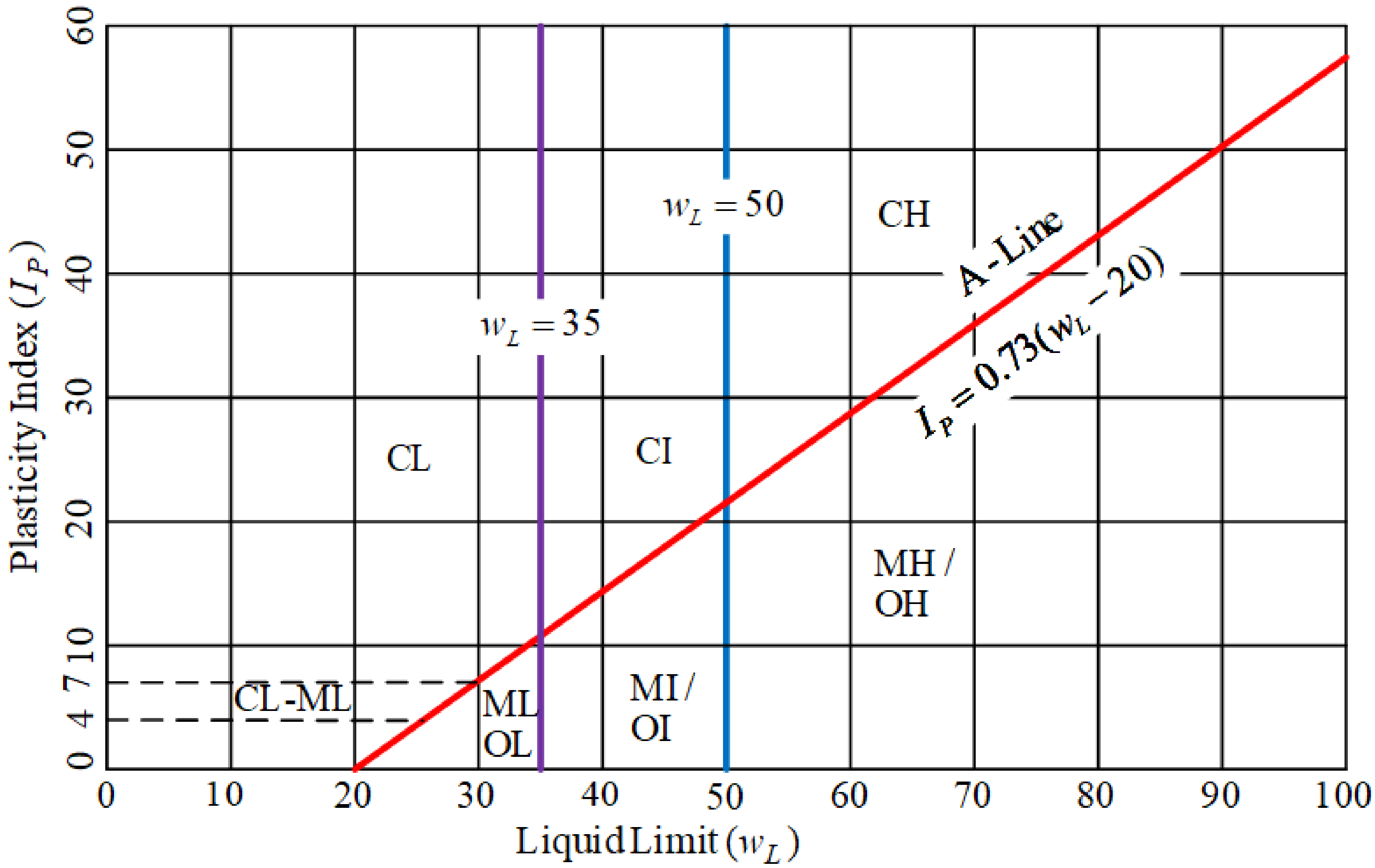
  MH: High compressible inorganic silt

- Organic silts and clays are plotted below A- line.

  OL : Low compressible organic silts and clays

  OI : Intermediate compressive organic silts and clays.

  OH : High compressible silts and clays.



Plasticity Chart

Black cotton soils (lies between 4 and 7) lie along a band partly above and partly below A-line.

- If the liquid limit of soil is exactly 35 then the soil is denoted by dual symbol $CL-CI$
- If a point is plotted exactly on A-line then the soil is denoted by dual symbol. $MI-CI$
- If PI lies between 4 and 7 then it is denoted by $CL-ML$

Classification for fine grained soil:

Soil type	Symbol
Gravel	G
Sand	S
Silt	M
Clay	C
Organic	O
Peat	Pt

Sub group	Symbol
Well graded	W
Poorly graded	P
Silty	M
Clayey	C
LL < 35%	L
35% <LL 50%	I
LL> 50%	H

Classification for fine grained soil:

Gravel:

1. Well graded Gravel : GW
2. Poorly graded Gravel : GP
3. Silty Gravel : GM
4. Clayey Gravel : GC

Sand:

1. Well graded Sand : SW
2. Poorly graded Sand : SP
3. Silty Sand : SM
4. Clayey Sand : SC

Silt:

1. Low compressible silt : ML
2. Intermediate compressible silt : MI
3. High compressible silt : MH

Clay:

1. Low compressible clay : CL
2. Intermediate compressible clay : CI
3. High compressible clay : CH

Organic soil:

1. Low compressible Organic soil : OC
2. Intermediate compressible Organic soi : OI
3. High compressible Organic soi : OH

Number of group symbols:

8 : Coarse

9 : Fine

1 : Peat

Total symbols = 18

Identification of organic soils:

1. Colour test : Dark colour (Black or dark brown)
2. Odour test : Bad odour
3. Liquid limit test : Test to be conducted before and after oven drying

- For organic soils, liquid limit decreases by more than 25% of its initial value after oven drying.

Boundary classifications:

1. CL – CI, CI – CH
2. ML – MI, MI – MH
3. OL – OI, OI – OH
4. MI – CI, MH – CH

- Corse particle should be written first.

  eg. MH - CH

Gravel:

GW : Fines < 5%, $C_u > 4$ and $C_c = 1\ to\ 3$

GP : Fines < 5% and for other gradation of C_u and C_c

GM : Fines < 12 %, $I_P < 4\%$ or Atterberg limit fall below A – line.

GM : Fines > 12 %, $I_P > 7\%$ with Atterberg limit fall above A – line.

- If the fines lies between 5% and 12%, it is representing border line case requiring dual symbol. Eg. GM – GC, GP – GM, GP – GC, GW – GM
- If I_P lies between 4% and 7%, it is a border line case and requiring dual symbol. Eg. GM – GC

Eg. Fines = 18%, $I_P = 5\%$, $\Rightarrow$ GM – GC

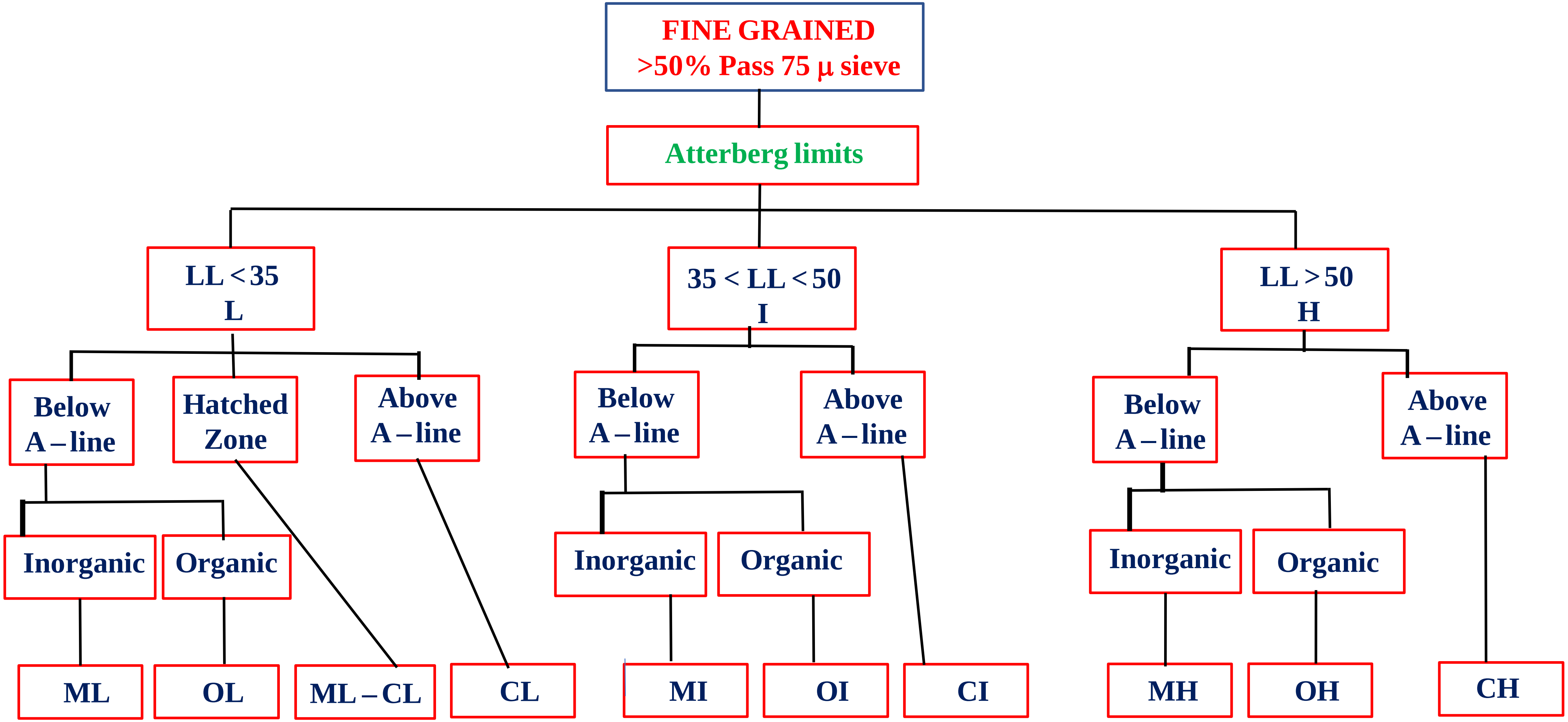
Fines = 4%, $C_u = 5$, $C_c = 2$, $\Rightarrow$ GW

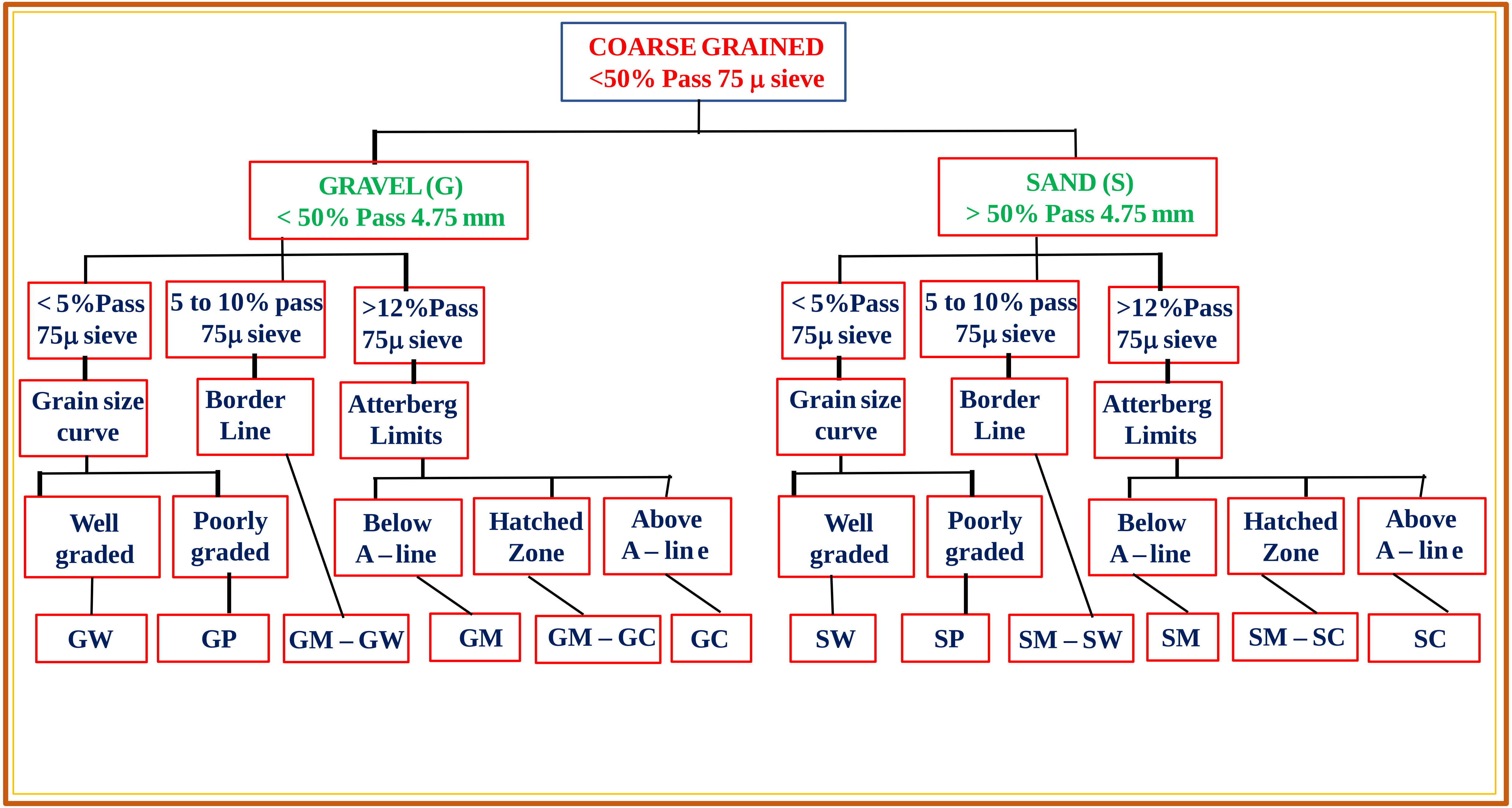
Fines = 18%, $I_P = 3\%$, $\Rightarrow$ GM

Fines = 10%, $C_u = 5\%$, $C_c = 2$, $I_P = 6\%$ $\Rightarrow$ GM – GC

For border line cases, the coarser is to be written first. Eg. MI – CI is correct and CI – MI is not correct.

For Sandy soils, above representation of symbols are valid except $C_u > 6$


FINE GRAINED
>50% Pass 75 µ sieve
Atterberg limits
LL < 35
L
35 < LL < 50
I
LL > 50
H
Below
A – line
Hatched
Zone
Above
A – line
Below
A – line
Above
A – line
Below
A – line
Above
A – line
Inorganic
Organic
Inorganic
Organic
Inorganic
Organic
ML
OL
ML – CL
CL
MI
OI
CI
MH
OH
CH


COARSE GRAINED
<50% Pass 75 μ sieve
GRAVEL (G)
< 50% Pass 4.75 mm
SAND (S)
> 50% Pass 4.75 mm
< 5%Pass 75μ sieve
5 to 10% pass 75μ sieve
>12%Pass 75μ sieve
< 5%Pass 75μ sieve
5 to 10% pass 75μ sieve
>12%Pass 75μ sieve
Grain size curve
Border Line
Atterberg Limits
Grain size curve
Border Line
Atterberg Limits
Well graded
Poorly graded
Below A – line
Hatched Zone
Above A – line
Well graded
Poorly graded
Below A – line
Hatched Zone
Above A – line
GW
GP
GM – GW
GM
GM – GC
GC
SW
SP
SM – SW
SM
SM – SC
SC

- Coarse grained soils which contain more than 12% fines(75µ) are classified as or if the fines are silty in character (below A- line), they are classified are GC or SC if the fines are clayey in character(above A-line)

- Coarse grained soils having 5 to 12% fines are border line cases and given a dual symbol.

Boulder Cobble Pebble Gravel Sand Silt Clay

Soil Structure

Soil Structure

It is a geometrical arrangement of soil particles in a soil mass.

The behaviour of soil depends on the soil structure.

Types of structures:

a. Single Grained Structure

b. Honey Comb structure

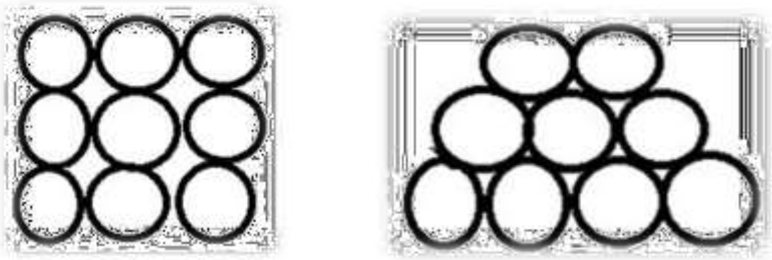
c. Flocculated structure

d. Dispersed Structure

e. Composite Structure

a. Single Grained Structure:

- Present in coarse grained soils such as gravel and sand.
- It is formed due to settlement of soil particles under gravitational forces.



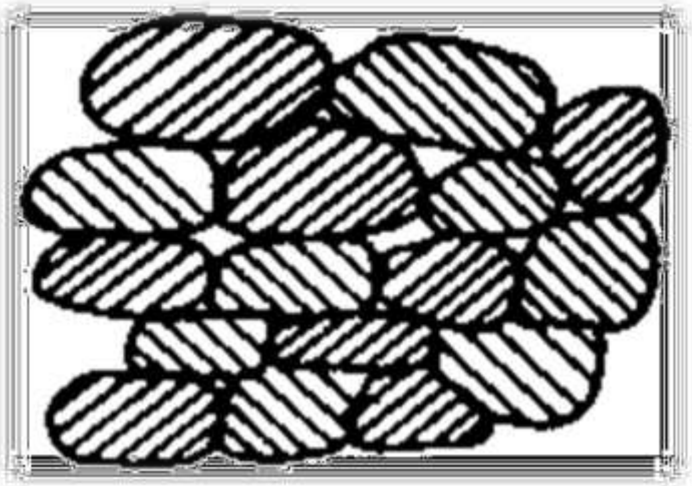
Loose Dense

Spheres in loosest and densest states

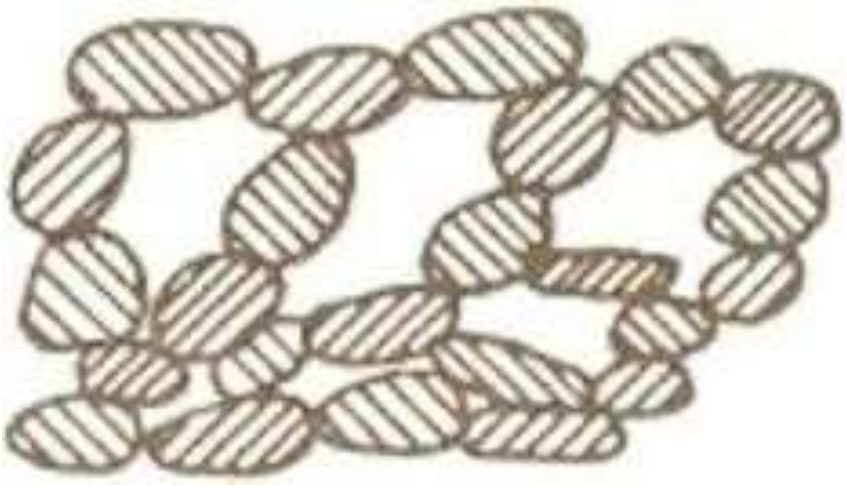
- If the particles are assumed as spheres the loosest and densest packing are shown above.
- When the particles are assumed as perfect spheres, the void ratio of soil in loosest state is 0.91, the void ratio for the densest state is 0.35.

b. Honey Comb Structure:

- Present in fine sands or silts.
- They can support the loads only under static conditions.
- Under vibrations and shocks the structure collapse and large deformations takes place.
- They have particle to particle contact.



Single Grained Structure

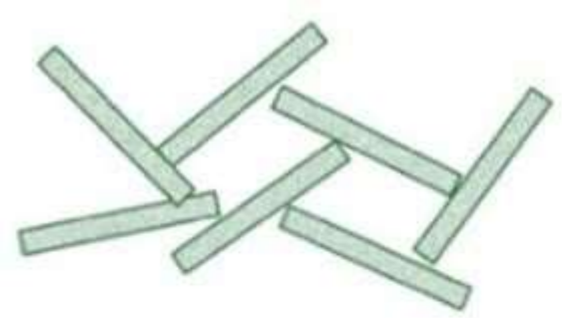


Honey Comb Structure

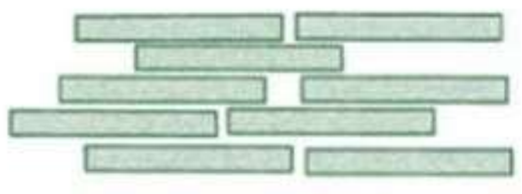
Soil structure in sands and silts

c. Flocculated Structure:

- Flocculated structure occurs in Clays.
- Edge to face orientation.
- The clay particles have large surface area and therefore the electrical forces are important in such soils.
- The Clay particles have a negative charge on the surface and a positive charge on the edges.
- Inter particle contact develops between the positively charge forces. This results in a Flocculated structure.



Flocculated Structure



Dispersed Structures

- The degree of Flocculation of clay depends upon presence of salt particles.
- Salt water acts as an electrolyte and reduces the repulsive forces between the particles.
- Clays settling out in a salt water solution have more flocculent structure than clays settling act in fresh water solution.
- have high shear strength, low compressibility and high permeability.

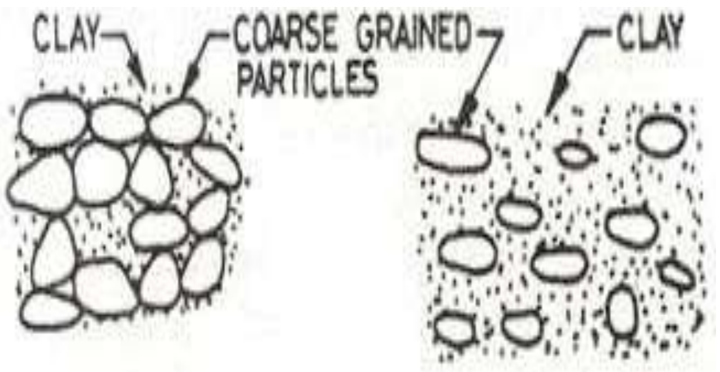
d. Dispersed Structures:

- Concentration of dissolved minerals in water
- Occur in remoulded clays.
- Platelets have face to face contact in more or less parallel arrays
- Formed when there is net repulsive force between particles.
- have low shear strength, high compressibility and low permeability.

e. Composite Structure:

- It is formed when soil contains different types of particles.

Types of Composite structure:



Coarse Grained Skeleton Clay Matrix Structure

Composite structure

a. Coarse Grained Skeleton:

- Formed when bulky cohesive particle is large compared with that of fine grained.

b. Clay Matrix Structure:

- Formed when amount of clay particles is very large as compared with bulky coarse grained particles.

Non-Clay Minerals:

- Non-clay minerals are granular and fine grained particles.
- Have low surface activities and do not contribute appreciable plasticity or cohesion. eg: Silts and Sands.

Clay Minerals:

- The Crystalline minerals whose surface activity is such that they develop cohesion and plasticity are called Clay Minerals.

Colloid:

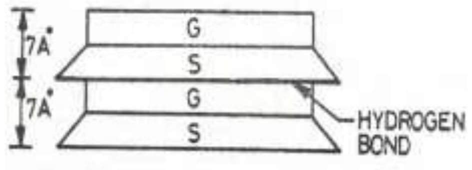
- A Colloid is a particle whose specific surface is so high that its behaviour is controlled by surface energy rather than mass energy.
- For colloids the specific surface varies between $600\text{-}10^5$ mm^2/mm^3.
- Soil particles less than 2 size are called Colloids.
- Gravitational forces and mass energy are predominant in coarse stained soils.
- Surface forces are predominant in fine grained soils.
- Size of grain is indirectly proportional to surface area.
- For same void ratio, water content is more in fine grained soils than in coarse grained soils.
- The behaviour of silt is governed by mass and surface energy.

Clay Mineralogy:

- In gravels and sands, rock minerals like quartz, feldspar, mica etc. are present.
- In clays, clay minerals are present.
- The shape of the clay particles in usually flaky.
- Important clay minerals are Kaolinite, Illite, Montmorillonite, Halloysite etc.

Kaolinite:

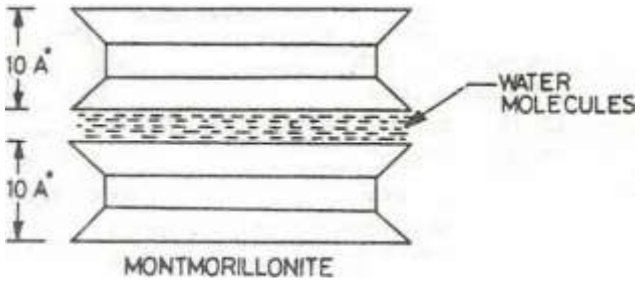
- Kaolinite consists of an aluminium sheet (Gibsite) combined with Silica sheet. The total thickness of structural unit is about Angstrom. $1\overset{0}{A} = 10^{-10}$m or 10^{-7} mm



KAOLINITE

- Stable mineral
- Causes no swelling and shrinkage eg: china clay
- The structural unit joined by Hydrogen bond.

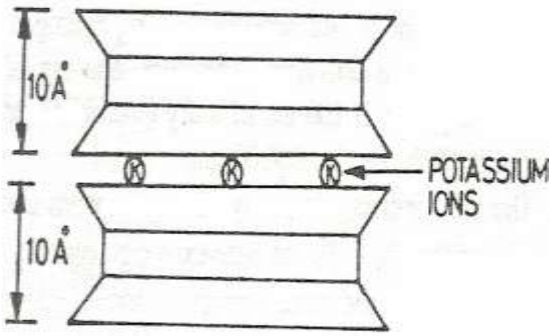
Montmorillonite:



- It is also called Smectile.
- It is a clay mineral composed of two Silica sheets and one Alluminium sheet. It is a 2:1 mineral.
- Alluminium sheet is sandwitched between two Silica sheets.
- The total thickness of each unit is $10\mathring{A}$
- In Montmorillonite isomorphous substitution takes place resulting in a relatively large net negative charge deficiency. Due to these factors the water enters easily between the layer causing layers to be separated. Hence Montmorillonite minerals are susceptable to substantial volume changes.
- They swell as the water gains entry into the lattice structure and shrink if water is removed.
- Na-Montmorillonite is more active than Ca- Montmorillonite
- Highest percentage is present in Bentonite followed by Black cotton soils.

Montmorillonite clay mineral has largest specific area (about 800 m^2/g)

Illite Mineral:



Illite

- The basic structural unit is similar to that of mineral Montmorillonite but with the difference that Potassium ions occupy positions between the structural units.
- Illite swells less than Montmorillonite. However swelling is more than Kaolinite.

Halloysite:

- Halloysite is a 1:1 clay mineral which has the same basic structure as Kaolinite, but in which the successive structural units are more randomly packed and are separated by a single molecular layer of water.
- If the water layer is removed by drying the properties of the mineral drastically change or approximately produce Kaolinite.

8.4 Soil Classsification

Numerical Questions

1. The properties of a sub grade soil are as follows

Liquid limit = 48%

Plastic limit = 38%

Percent finer than 0.075 mm = 55%

The soil is classified as

a. CI b. CH **c.** MI d. MH

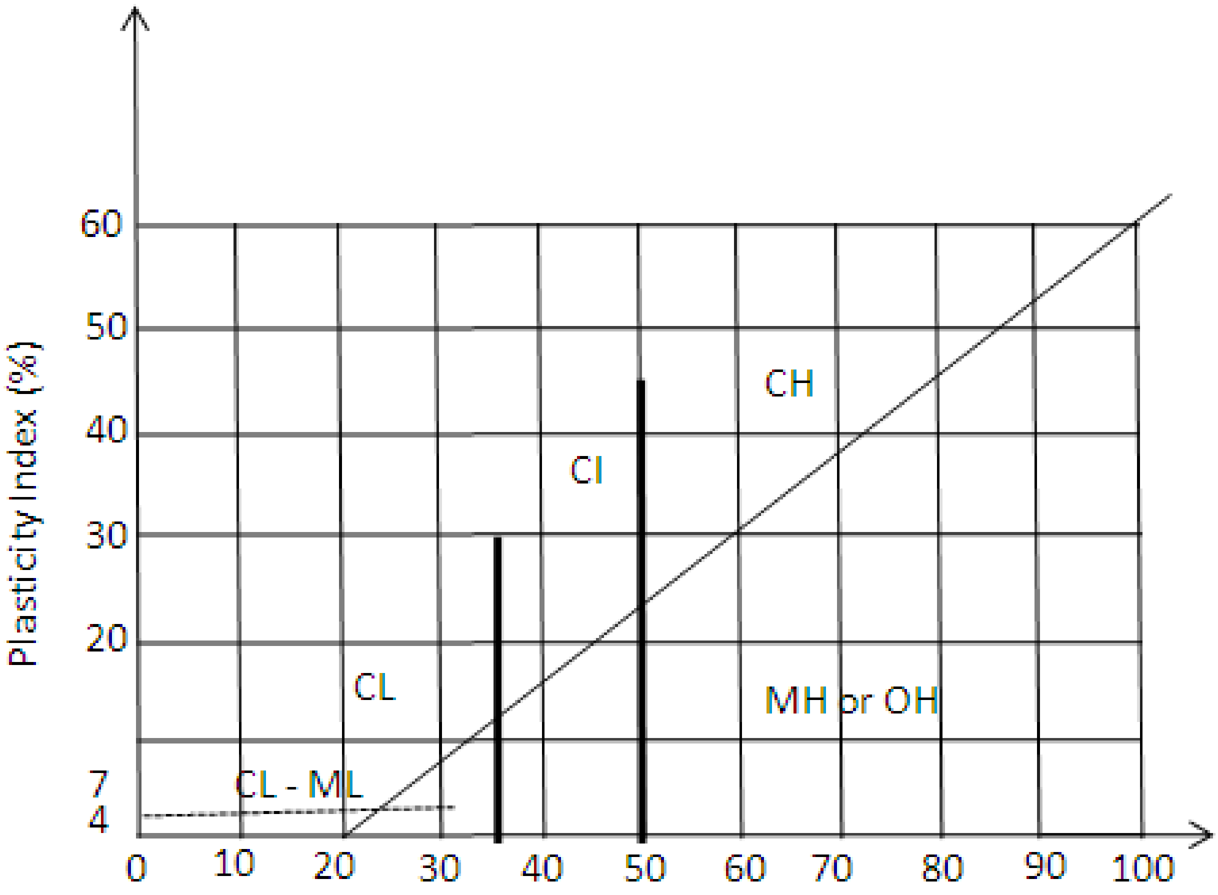
Ans. C

Solution:

Since the percent finer than 0.075 mm is more than 50%, the soil is fine grained soil.

Plasticity Index, $I_P = 48 - 38 = 10\%$

From fig. for w_L = 48% and I_P = 10%, the soil can be classified as MI or OI


Plasticity Index (%)
60
50
40
30
20
7
4
0
10
20
30
40
50
60
70
80
90
100
CH
CI
CL
MH or OH
CL - ML

2. A soil sample is found to have the following properties

Percent passing through 75μ sieve = 14%

Percent passing through 4.75 mm sieve = 72%

Uniformity Coefficient = 8

Coefficient of Curvature = 2.7

Plasticity Index = 4%

The soil is classified as

a. SW b. SM **c.** SW – SM d. SP – SM

Ans. c $I_P = 48 - 38 = 10\%$

Explanation:

Since less than 50% of soil is passing through 75μ sieve, the soil is course grained.

Since more than 50% passing through 4.75 mm sieve, the soil is sandy (s)

Since $C_u > 6$ and C_c lies between 1 and 3, the soil is well graded

Since $I_P < 4$; it in silty

The soil is classified as SW – SM

3. A sub grade soil sample is found to have the following properties

Percentage of soil passing through 75μ sieve = 64%

Liquid limit = 56%

Plastic limit = 25%

The soil is classified as

a. MH **b.** CH c. MI d. CI

Ans. b

Explanation:

Since the percentage of soil passing through 75μ sieve is more than 50%, the soil is fine grained soil.

Plasticity index, $I_P = w_L - w_P$ = 56 – 25 = 31%

From fig, for w_L = 56% and I_P = 31%, the soil can be classified as CH

8.4 Soil Classification Previous GATE Questions

01. The maximum possible value of Group Index for a soil is…… GATE CE 1991

Ans. 20

Explanation:

Group index, $GI = 0.2a + 0.005a.c + 0.01b.d$

a: Portion of material passing 0.075 mm sieve greater than 35 and not exceeding 75%. (0 – 45%)

b: Portion of material passing 0.075 mm sieve greater than 15 and not exceeding 35%. (0 – 20%)

c: value of liquid limit in excess of 40 and less than 60. (0 – 20%)

d: value of plasticity index exceesding and not more than 30. (0 – 20%)

GI varies in the range of 0 to 20. $0 < GI < 20$

The maximum value of Group index for a soil is **20**

02. Write True / False in the answer book. A soil having a uniformity coefficient smaller than about 2 is considered ‘uniform’. GATE CE 1992

Ans. True

Explanation:

Coefficient of uniformity, $C_u = \frac{D_{60}}{D_{10}}$

D_{60} : Particle size in mm such that 60% of the soil is finer than this size.

D_{10} : Particle size in mm such that 10% of the soil is finer than this size.

For uniformly graded soil, C_u is nearly 1

For a well graded gravel, $C_u > 4$

For a well graded sand, $C_u > 6$

Therefore, the soil having a uniformity coefficient smaller than about 2 is considered uniform.

03. Write True / False in the answer book. The ‘A’ line in the plasticity chart separates organic clays from inorganic clays. GATE CE 1992

Ans. True

Explanation:

Organic silts and clays are plotted below ‘A’ line and inorganic silts and clays are plotted above ‘A’ line.

4. The description ‘sandy silty caly’ signifies that GATE CE 1992

a. the soil contains unequal proportions of the three constituents, in the order, sand > silt > clay

b. the soil contains equal proportions of sand, silt and clay

c. the soil contains unequal proportions of the three constituents such that clay > silt > sand

d. there is no information regarding the relative proportions of the three

Ans. C

Explanation:

Sandy silty clay means the soil contain unequal proportions of the three constituents such that clay > silt > sand.

05. A soil having particles of nearly the same size is known as 1995

a. well graded **b.** uniformly graded c. poorly graded d. gap graded

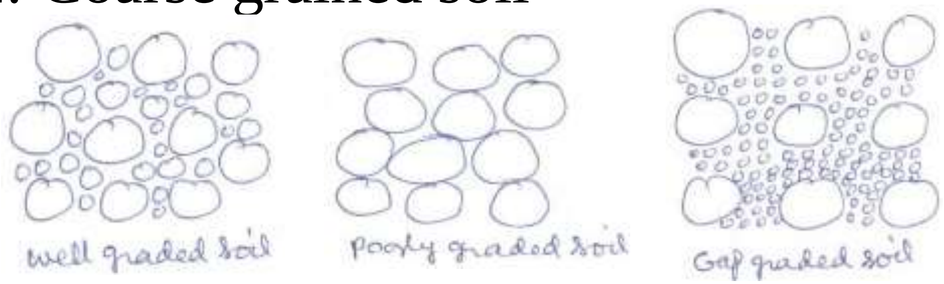
Ans. b

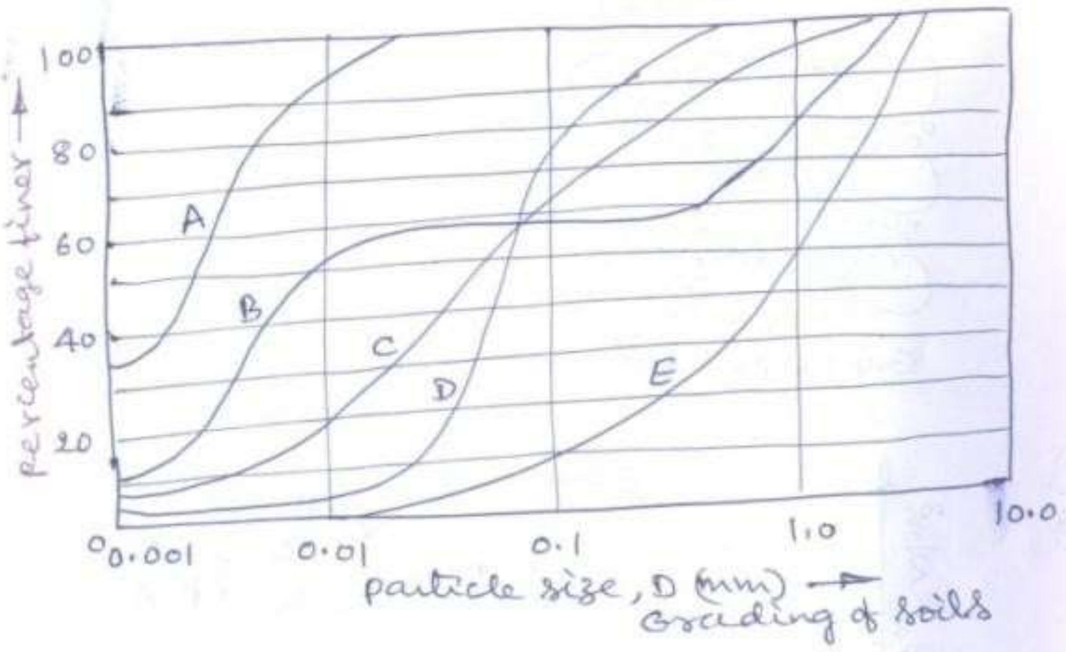
Explanation:

A: Fine grained soil B: Gap graded soil

C: Well graded soil D: Uniform graded soil

E: Coarse grained soil





- A well graded soil contains particles of a wide range of sizes and has a good representation of all sizes.
- A uniformly graded soil has most of its particles at about the same size.
- A poorly graded does not have a good representation of all sizes of particles.
- A gap-graded soil has an excess or deficiency of certain particle sizes or a soil that has at least one particle size missing

6. The equation of the A-line in the plasticity chart is………..   GATE CE 1995

Ans. $I_P = 0.73(w_L - 20)$

Explanation:

The equation of the ‘A’ line in the plasticity chart is $I_P = 0.73(w_L - 20)$

I_P : Plasticity Index

w_L : Liquid limit

07. The particle size distribution curves are extremely useful for the classification of

GATE CE 1996

a. fine grained soils
b. coarse grained soils
c. both coarse grained and fine grained soils
d. silts and clays

Ans. c

Explanation:

The particle size distribution curves are useful for the classification of both coarse gained and fine grained soils.

8. Data from a sieve analysis conducted on a given sample of soil showed that 67% of the particles passed through 75 micron IS sieve. The liquid limit and plastic limit of the finer fraction was found to be 45 and 33 percents respectively. The group symbol of the given soil as per IS:1498-1970 is GATE CE 2002

a. SC **b.** MI c. CH d. MH

Ans. B

Explanation:

Percentage of the soil particles passing through 75μ sieve = 67%

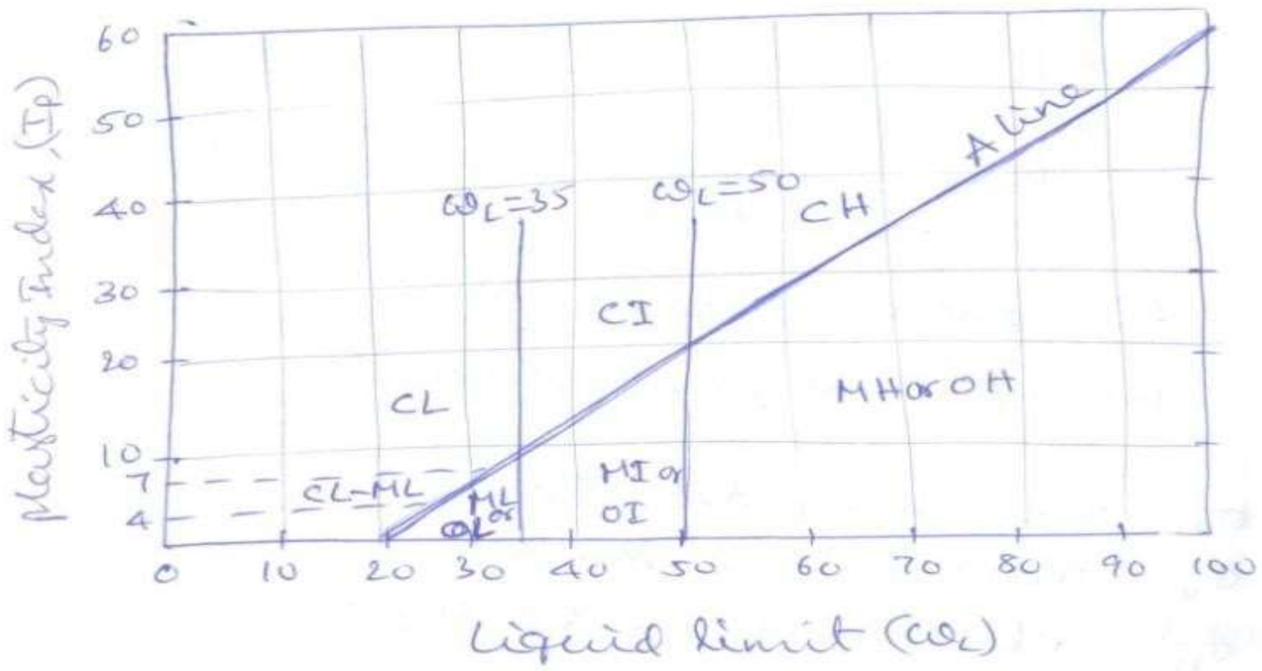
Liquid limit, $w_L = 45\%$

Plastic limit, $w_P = 33\%$

Plasticity index, $I_p = w_L - w_P = 45 - 33 = 12\%$

Since more than 50% of the soil particles are finer than 75μ size, the soil is fine grained soil.

I_P value for A-line, $I_P = 0.73(w_L - 20) = 0.73(45 - 20) = 18.25$



The soil corresponding to $w_L = 45\%$ and $I_P = 12\%$ lies below the A- line is either M or O. Since $35\% < w_L < 50\%$, the soil is medium compressible (I). Hence, the soil is classified as MI or OI.

09. A soil mass contains 40% gravel, 50% sand and 10% silt. This soil can be classified as GATE CE 2005

a. silty sandy gravel having coefficient of uniformity less than 60.

b. silty gravelly sand having coefficient of uniformity equal to 10.

c. gravelly silty sand having coefficient of uniformity greater than 60.

d. gravelly silty sand and its coefficient of uniformity cannot be determined.

Ans. c

Explanation:

As 50% of the soil is sand, the soil is sand with gravel and silt as ingredients.

Therefore, the soil is classified as gravelly silty sand.

Gravel size > 4.75 mm

Sand size > 75 μ

Size mm	% Retained	Cumulative % Retained	% finer
4.75	40	40	60
75 μ	50	90	10

D_{60} = 4.75 mm $D_{10} = 75\mu = 0.075 mm$

Uniformity coefficient, $C_u = \frac{D_{60}}{D_{10}} = \frac{4.75}{0.075} = 63.33$

Hence, the soil is gravelly silt sand with, $C_u > 60$

Common Data for Question 10 and 11 :

Laboratory sieve analysis was carried out on a soil sample using a complete set of standard IS sieves. Out of 500g of soil used in the test, 200g was retained on IS 600 μ sieve, 250g was retained on IS 500 sieve and the remaining 50g was retained on IS 425μ sieve. GATE CE 2006

10. The coefficient of uniformity of the soil is

a. 0.9 b. 1.0 c. 1.1 **d.** 1.2

Ans. d

Solution: Sieve analysis of sample

S.No	Sieve size,	Weight retained, gm	Cumulative Weight retained, gm	Cumulative % Weight retained	% passing through
1	600	200	200	40	60
2	500	250	450	90	10
3	425	50	500	100	0

D_{60}: 60% finer size = 600 μ

D_{10}: 10% finer size = 500 μ

Coefficient of uniformity, $C_u = \frac{D_{60}}{D_{10}} = \frac{600}{500} = 1.2$

11. The classification of the soil is

a. SP b. SW c. GP d. GW

Ans. a

Explanation:

Greater percentage of the soil passes through 4.75 mm sieve since more than 50% of the soil pass through 600 μ sieve. Hence the soil is sandy soil. For a sandy soil to be considered as well graded, C_u should be greater than 6.0. In this case $C_u = 1.2$, the soil is poorly graded. Therefore the soil is classified as poorly graded sand (SP).

12. Sieve analysis on a dry soil sample of mass 1000 g showed that 980 g and 270 g of soil pass through 4.75 mm and 0.075 mm sieve, respectively. The liquid limit and plastic limits of the soil fraction passing through 425 μ sieves are 40% and 18% respectively. The soil may be classified as GATE CE 2007

a. SC b. MI c. CI d. SM

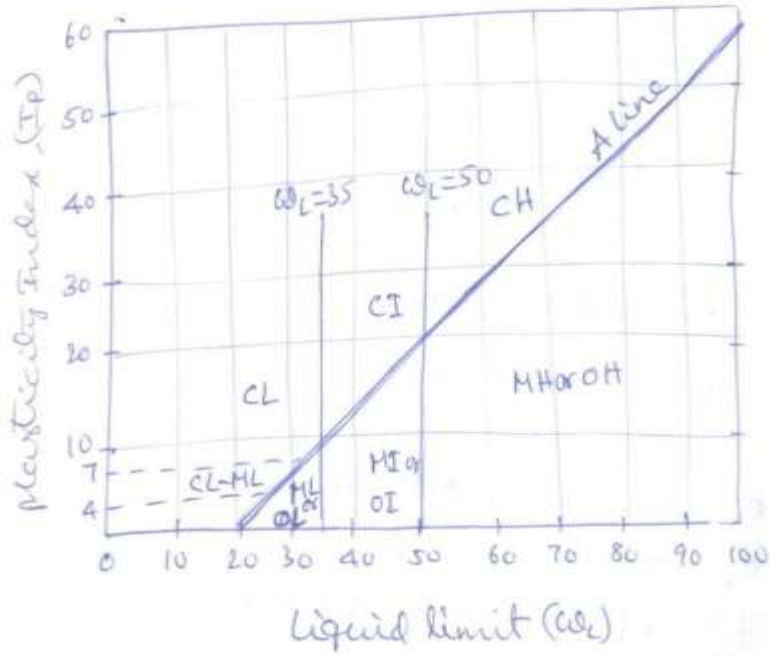
Ans. A

Explanation:

- Weight of dry soil sample = 1000 g
- Weight of soil passing through 4.75 mm sieve =

passing through 0.075 mm sieve = 270 g Liquid l

- Plastic limit, $w_P =$ 18%



Plasticity index, $I_P = w_L - w_P = 40 - 18 = 22\%$

According to unified soil classification system, if 50% or less pass through 0.075mm sieve, it is coarse grained soil.

Again if 50% or more of coarse grained soil is retained on 4.75 mm sieve, it is classified as gravel(G), otherwise it is termed as sand(S). Therefore, the given sample is sand(S).

The given sample pass through 0.075 mm is more than 12%.

Plasticity index of A-line, $I_P = 0.73(w_L - 20) = 0.73(40 - 20) = 14.6$

According to plasticity chart, for $w_L = 40\%$ and $I_P = 22\%$ the soil is classified as clay(C)

Therefore, the sample is **clayey sand (SC).**

13. Group symbols assigned to silty sand and clayey sand are respectively

GATE CE 2008

a. SS and CS   b. SM and CS   **c.** SM and SC   d. MS and CS

Ans. c

Explanation:

The symbols used for soil classification

Sand	S
Silt	M
Clay	C

Silty sand contains sand and silt – SM

Clay sand contains sand and clay – SC

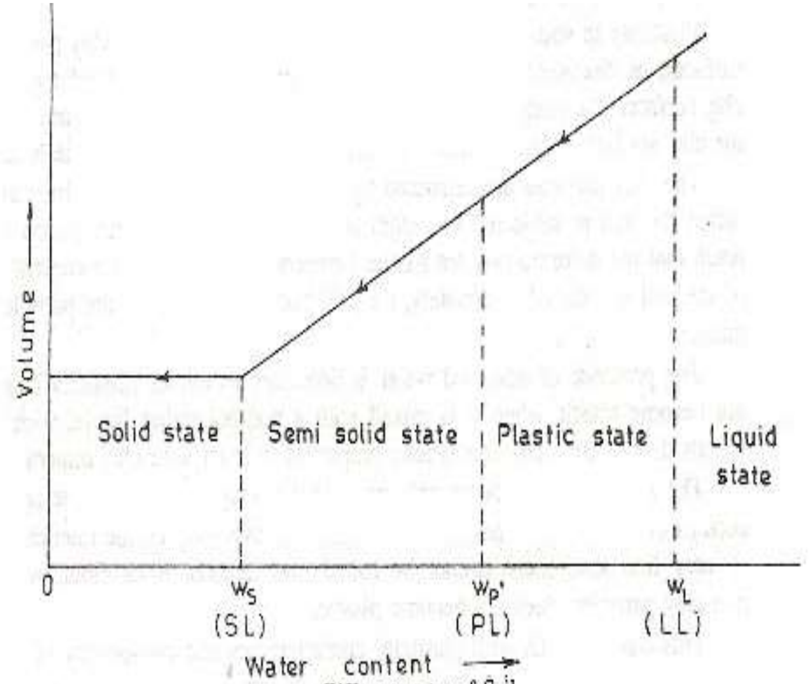
14. The liquid limit (LL), plastic limit (PL) and shrinkage limit (SL) of a cohesive soil satisfy the relation GATE CE 2008

a. LL>PL>SL **b.** LL>PL<SL c. LL<PL<SL d. LL<PL>SL

Ans. b

Explanation:

The relation of Atterberg limits with volume of soil is shown in figure.



Different states of Soil.

From the graph **LL** > **PL** > **SL**

15. The laboratory test results of a soil sample are given below: GATE CE 2009

Percentage finer than 4.75 mm = 60

Percentage finer than 0.075 mm = 30

Liquid Limit = 35%

Plastic Limit = 27%

The soil classification is

a. GM **b.** SM c. GC d. ML-MI

Ans. b

Percentage finer than 4.75mm = 60

Percentage finer then 0.075mm = 30

Liquid limit, $w_L = 35\%$

Plastic limit, $w_P = 27\%$

Plasticity Index, $I_P = w_L - w_P = 35 - 27 = 8\%$

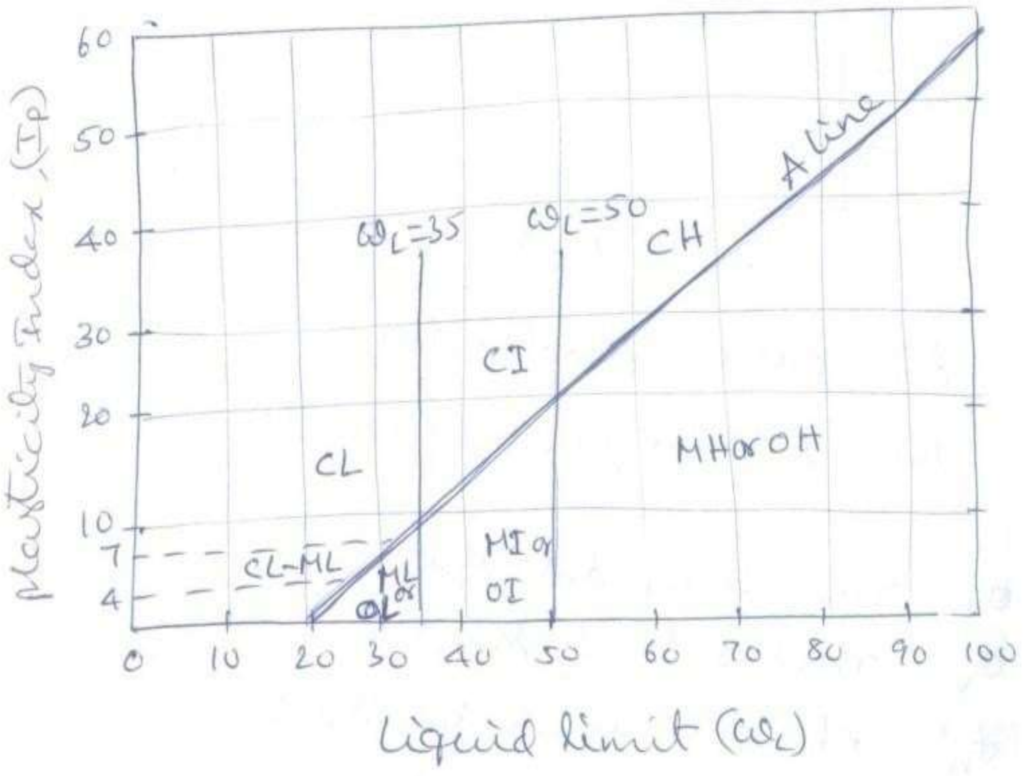
Fine grained soils are those having **50% or more pass** through 75 μ sieve (0.075 mm). It is designated as **sand (S)** if **50% or more pass** through **4.75 mm** sieve otherwise designated as **gravel (G)**.

Since the percentage finer than 4.75 mm is 60%, it is designated as sand (S). Further, percentage finer than 75μ is 30 which is more than 12%, observe the liquid limit and plastic limit on the plasticity chart.

Plasticity index corresponding to A-line, $I_P = 0.73(w_L - 20) = 0.73(35 - 20) = 10.95$

The point corresponding to $w_L = 35\%$ and $I_P = 8\%$ lies below A- line on the Plasticity chart. It is designated as M or O.

Therefore, the **soil** is classified as **SM.**



16. 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 is represented by the letter symbols

GATE CE 2010

a. CL b. CI **c.** CH d. CL-ML

Ans. c

Explanation:

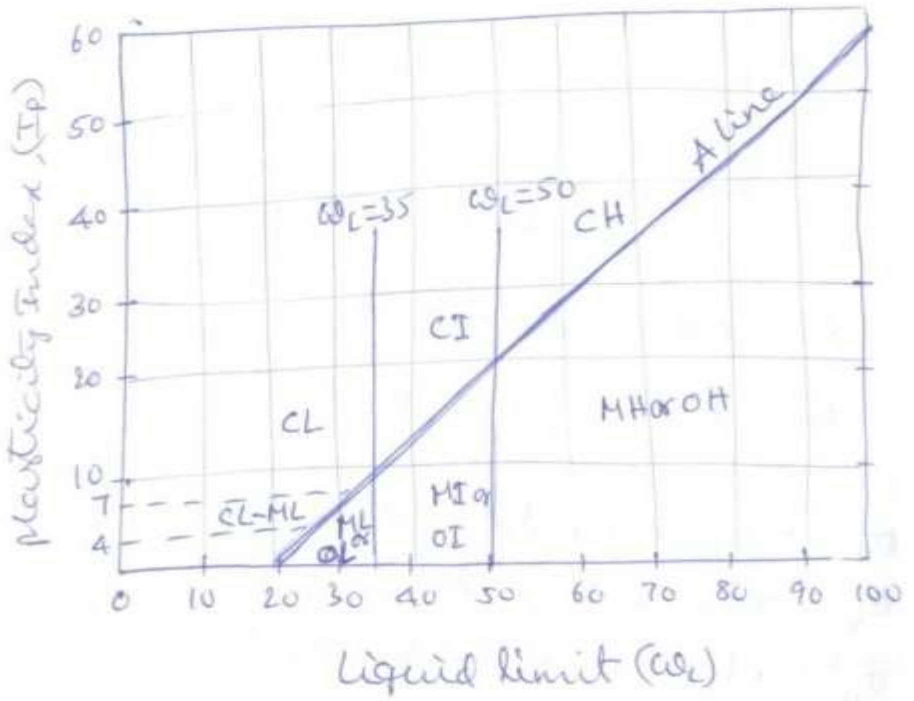
Liquid limit, $w_L = 60\%$

Plastic limit, $w_P = 20\%$

Plasticity index, $I_P = w_L - w_P = 60 - 20 = 40\%$

The plasticity index corresponding to A-line

$$I_P = 0.73(w_L - 20) = 0.73(60 - 20) = 29.2$$



17. As per the Indian standard soil classification system, a sample of silty clay with liquid limit of 40% and plasticity index of 28% is classified as GATE CE 2012

a. CH **b.** CI c. CL d. CL-ML

Ans. b

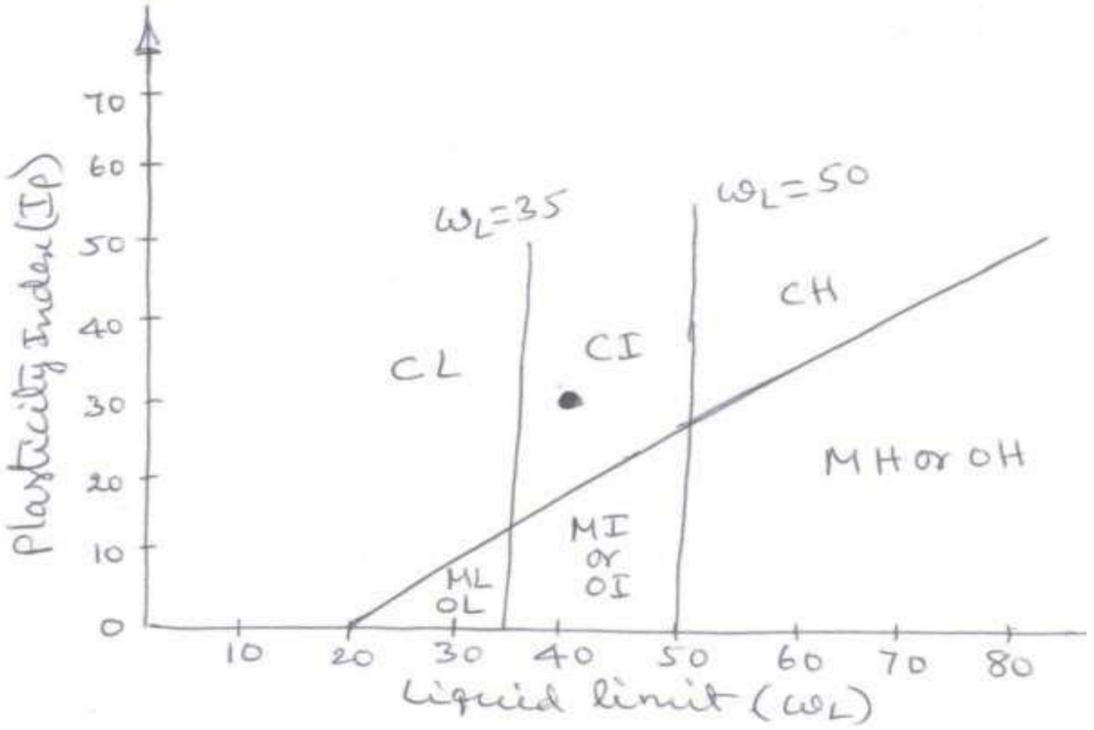
Solution:

Liquid limit, $w_L = 40\%$

Plasticity limit, $w_P = 28\%$

As per the plasticity chart, the value of plasticity index corresponding to A-line is given by

$$I_P = 0.73(w_L - 20) = 0.73(40 - 20) = 14.6\%$$



I_p of the sample lies above the A line. w_L is more than 35% and less than 50%

Therefore, the **soil** is classified as **CI**.

18. As per Indian Standard Soil Classification System (IS: 1498-1970), an expression for A-line is GATE CE2 2014

a. $I_P = 0.73(w_L - 20)$

b. $I_P = 0.70(w_L - 20)$

c. $I_P = 0.70(w_L - 10)$

d. $I_P = 0.73(w_L - 10)$

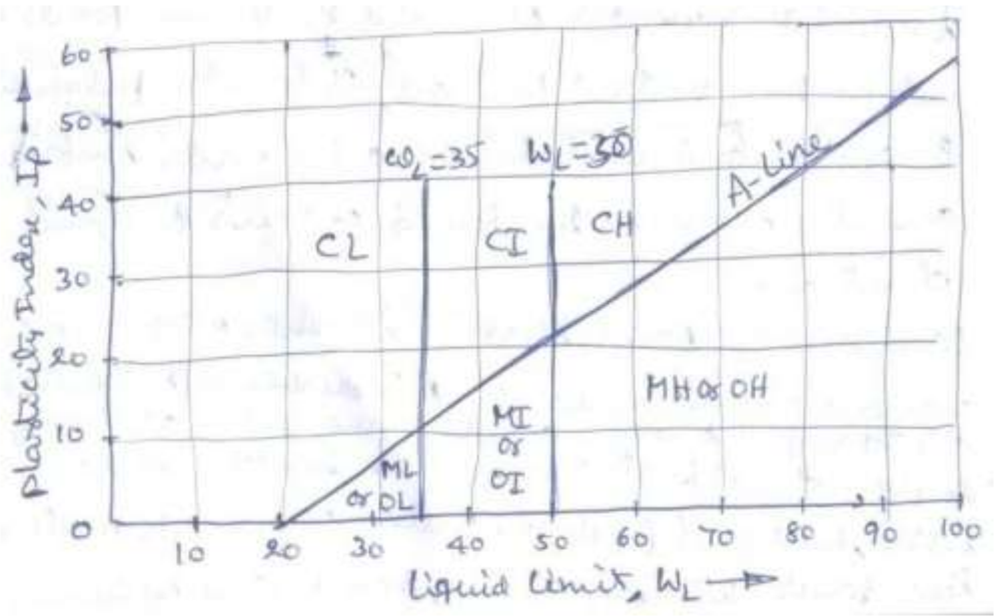
A ns. a

Explanation:

As per the plasticity chart, the value of plasticity index corresponding to A-line is given by $I_p = 0.73(w_L - 20)$

I_p : Plasticity Index

w_L : Liquid limit



19. A fine grained soil is found to be plastic in the water content range of 26-48%. As per Indian Standard Classification System, the soil is classified as GATE CE1 2016

a. CL b. CH c. CL-ML **d.** CI

Ans. d

Solution:

Soil is plastic in the water content range of 26-48%

Liquid limit, $w_L = 48\%$

Plasticity index, $I_P = w_L - w_P = 48 - 26 = 22\%$

Plastic limit, $w_P = 26\%$

Since w_L is in the range of 35-50%, the soil is intermediate compressible.

From A-line, $I_p = 0.73(w_L - 20) = 0.73(48 - 20) = 20.44\%$

The soil lies above the a-line, indicates that it is clay

$\therefore$ The soil classification is **CI**

20. The notation as per Indian Standard Soil Classification System refers to

GATE CE2 2019

a. sandy clay   b. silty clay   c. clayey silt   **d.** clayey sand

Ans. d

Explanation:

The symbol SC stands for clayey sand

Soil structure Previous GATE Questions

01. Write True / False in the answer book. The charge on Kaolinite is due to one aluminium substitution for every four hundredth silicon ion.

GATE CE 1992

Ans. False

Explanation: Kaolinite consists of an **aluminum sheet** (Gibsite) combined with slilica sheet.

2. The swelling nature of black cotton soil is primarily due to the presence of

GATE CE 1993

a. Kaolinite b. Illite **c.** Montmorillonite d. Vermiculite

Ans. c

Explanation: In Montmorillonite isomorphous substitution takes place resulting in a relatively large net negative charge deficiency. Due to these factors the water enters easily between the layer causing layers to be separated. Hence Montmorillonite minerals are susceptible to substantial volume changes. It swells as the water enters into the structure and shrink if the water is removed. Montmorillonite is highly plastic and has little internal friction. Black cotton soil contains Montmorillonite.

03. The shape of clay particle is usually

GATE CE 1997

a. angular **b.** flaky c. tubular d. rounded

Ans. b

Shape of clay particle is usually **flaky**.

4. Deposit with flocculated structure is formed when GATE CE 2009
   a. Clay particles settle on sea bed
   b. Clay particles settle on fresh water lake bed
   c. Sand particles settle on river bed
   d. Sand particles settle on sea bed

Ans. a

Explanation: Flocculated structure of clay platelets is formed when there **are edge to edge** contacts between the platelets. Such a structure is formed if the net electrical forces between adjacent soil particles at the time of deposition are attractive forces. If there is a concentration of dissolved minerals in the water (eg. Marine water) the tendency of flocculation is increased. Deposit with flocculated structure is formed when clay particles settle on sea bed.

05. The clay mineral primarily governing the swelling behaviour of black cotton soil is GATE CE2 2014

a. Halloysite b. Illite c. Kaolinite **d.** Montmorillonite

Ans. d

Explanation: The clay mineral primarily governing the **swelling behavior** of black cotton soil is **Montmorillonite**. In Montmorillonite, isomorphous substitution takes place resulting in a relatively large net negative charge deficiency. Due to this, water enters easily between the layer causing layers to be separated. Hence, Montmorillonite minerals are susceptible to substantial volume changes.

06. The clay mineral, whose structural units are held together by potassium bond is

GATE CE2 2018

a. Halloysite **b.** Illite c. Kaolinite d. Smectite

Ans. b

Halloysite:

Kaolinite: Hydrogen bond

Illite: Ionic bond/potassium bond

Montmorillonite: Water bond

Smectile: