Unit - 1

INTRODUCTION

Nature of soil - Problems with soil - phase relation - Sieve analysis - sedimentation analysis - Atterberg limits - classification for engineering purpose - BIS Classification system - Soil compaction - factors affecting compaction - field compaction methods and monitoring.

Unit - 1

1st

1. Phase relation
2. Sieve Analaysis
3. Sedimentation

2nd

soil classification
Compaction
cetterberg limit

unit - 2

1st

1. Stress distribution in terms σ, σ', u
2. Permeability measurement

2nd

1. Quick sand
2. Laplace equation
3. Flownent

Pg no: 450, 451 (18.11), 452 (Pore pressure parameters)

unit - 3

stress distribution
Boussinglle,

2nd

Settlement
Terazaghi
Time rate of conso

unit - 4

Mohr coulomb theory
Find the strength parame
Problm

Measurement of shear strength (4)

unit - 5

Infinite slope
finite slope

unit - 4

Pg no: 434, 436, 442, 443 (eg 18.1, 18.2, 18.3, 18.4), 448 (eg: 18. 18.

03/01/13

Unit - 1

Introduction

Soil : (unconsolidate Material)

Formed by the disintegration of rocks.
by physical weathering or chemical weathering.

Soil formed by physical weathering is also known as cohesion less soil.

Soil formed by chemical weathering is also known as cohesive soil.

Cohesion less soil :

Eg : Sand [Min 0.075mm to 4.75 mm]

Gravel [4.75mm to 80mm]

Global [80mm to 300mm]

Boulders [More than 300mm]

Cohesive soil :

Eg : Clay

Soil Formation :

1. ~~Radial~~ Residual Soil :

The soil formed at the same place of the formation from the parent rock.

2. <u>Transported Soil</u>:

The soil that is formed away from the place of formation [parent rock].

- Water transported soil Eg : Alluvial soil (river deposits)
- Lacustrine [Lake deposits]
- Marine deposits [Suspension in sea water]
- Glacial drift [Ice deposits]

Soil Mechanics :

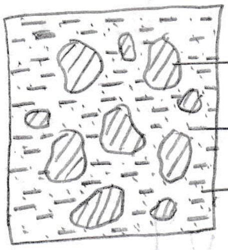
* Father of Soil Mechanics Dr. Karl Terzaghi
* It was developed in the year 1925.

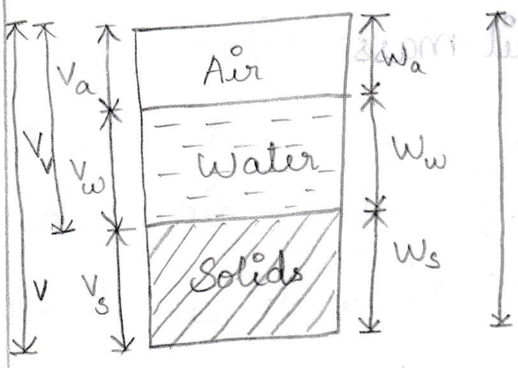
2m ☆ <u>Definition</u>:

According to Terzaghi, "Soil Mechanics is the application of laws of mechanics and hydrallics to engineering problems dealing with sediment and other unconsolidate accumulation of solid particles produced by the mechanical and chemical disintegration of rocks regardless of whether or not they contain an admixture of organic constituent."

Phase Relationship :

Soil possess 3 phase system.
- → Air
- → water
- → Soil grains (or) Soil solids





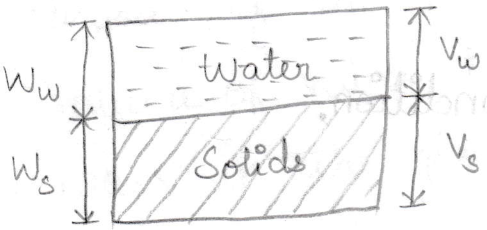
W_a - negligible

V_v - Volume of voids

$$\therefore V_v = V_w + V_a$$

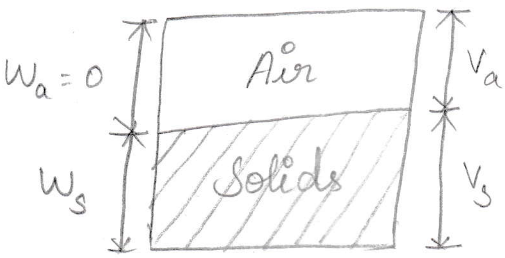
* In case of fully saturated condition soil mass has 2 phase system.

    1. Soil solid
    2. Water



$$\therefore V_v = V_w$$

* In case of fully dried condition soil mass has 2 phase system.
    1. Soil Solid
    2. Air



$$\therefore V_v = V_a$$

Symbols :

V_s = Volume of solids

V_a = Volume of air

V_w = Volume of water

V_v = Volume of Voids [ie., $V_w + V_a$]

V = Total Volume of soil mass

$$V = V_w + V_a + V_s$$

W_s = Weight of Solids

W_a = Weight of air ($W_a = 0$)

W_w = Weight of water

W = Total weight of soil mass

$$W = W_s + W_w + W_a$$

Here, $W_a = 0$

$$W = W_s + W_w$$

* Fully Saturated Condition,

$$V = V_w + V_s$$

$$W = W_s + W_w$$

* Fully Dried Condition,

$$V = V_a + V_s$$

$$W = W_s$$

Technical terms :

Based on Volumes :

1. Void ratio :

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

$e \leq 1$ (or) ≥ 1

* The ratio of volume of void to volume of solids in the given mass is known as void ratio of the given soil sample.
* It is dimension less.
* It is expressed in decimal only

'e' value is high for loose soil

coarse grain = 0.5 to 0.[illegible]
fine = 0.7 to 1.5

2. Porosity (% of Voids):

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

* Porosity of the given soil is the ratio of the volume of voids to the total volume of soil mass in the given soil mass.
* It is expressed in percentage.
* The value of porosity is always less than 10[illegible]

Relationship between Void ratio and Porosity:

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

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

(×ly & ÷) by V_v

Here, $V = V_s + V_w + V_a$
$= V_s + V_v$

Here, $V_v = V_w + V_a$

$$= \frac{1}{\frac{V_s}{V_v} + 1}$$

$$= \frac{1}{\frac{1}{e} + 1} = \frac{1}{\frac{1+e}{e}} = \frac{e}{1+e}$$

$$\therefore n = \frac{e}{1+e}$$

3. Degree of Saturation:

Degree of saturation of a given soil mass is the ratio of Volume of water to Volume of Voids in the given soil sample.

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

* If fully saturated condition,

$$S_r = \frac{V_w}{V_w + V_a} \times 100$$

$\therefore V_a = 0$

$$\therefore S_r = 100\%$$

* If fully dried condition, (No water)

$$S_r = 0\%$$

* If partially saturated,

$$0 < S_r < 100\%$$

Overall,

S_r vary from $0 \le S_r \le 100\%$

4. Air Content :

$$a_c = \frac{V_a}{V_v} \times 100$$

* It is the ratio of Volume of air to Volume of voids in the given soil sample.
* It is expressed in percentage.

Relationship between S_r and a_c :

$$a_c = \frac{V_a}{V_v}$$

Here, $V_v = V_w + V_a$

$V_a = V_v - V_w$

$$= \frac{V_v - V_w}{V_v}$$

$$= 1 - \frac{V_w}{V_v}$$

$$\therefore a_c = 1 - S_r$$

5. Percentage of Air Voids :

$$n_a = \frac{V_a}{V} \times 100$$

* It is ratio of the volume of air to total Volume of soil mass of the given soil sample.
* It is expressed in percentage.

Relationship Between n, S_r and n_a :

$$n_a = \frac{V_a}{V}$$

$$= \frac{V_v - V_w}{V_v + V_s}$$

$$= \frac{\frac{V_v}{V_v} - \frac{V_w}{V_v}}{\frac{V_v}{V_v} + \frac{V_s}{V_v}}$$

$$= \frac{1 - \frac{V_w}{V_v}}{1 + \frac{V_s}{V_v}}$$

$$= \frac{1 - S_r}{1 + \frac{1}{e}}$$

$$= (1 - S_r)\frac{e}{1+e}$$

$$= (1 - S_r)\, n$$

$$= a_c \cdot n$$

$$\therefore n_a = a_c \cdot n$$ ✓

Here, $V_v = V_w + V_a$

$V_a = V_v - V_w$

$V = V_w + V_a + V_s$

$= V_v + V_s$

Here, $n = \frac{e}{1+e}$

$a_c = (1 - S_r)$

Based on Weight :

1. Water Content (or) Moisture Content :

* It is the ratio of weight of water to weight of solids in term of percentage is known as water content (or) moisture content.

General Soil $(w) = 60\%$

Clay Soil $(w) = 500\%$

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

Based on Volume and Weight :

1. Bulk unit weight (or) Total unit weight (or) unit weight of soil mass : (γ)

* It is the ratio of weight to the volume.

$$\gamma_{bulk} = \frac{W}{V}$$

* It unit is kN/m^3 or N/m^3 or kgf/m^3 or gm/cc

2. Dry Unit Weight : (γ_d)

$$\gamma_d = \frac{W_s \text{ (or) } W_d}{V} \quad kN/m^3$$

Value γ_d is about 14 to 18 kN/m^3

Note :

$$\gamma_{bulk} > \gamma_d$$

3. Saturated Unit Weight :

$$\gamma_{sat} = \frac{W_{sat}}{V} \quad (kN/m^3)$$

↓

22 kN/m^3

$$\gamma_{sat} \geq \gamma_{bulk}$$

4. Submerged Unit Weight :

$$\gamma_{sub} \text{ (or) } \gamma' = \frac{W_{sub}}{V}$$

$$\gamma_{sub} < \gamma_{sat}$$

$$= \frac{W_{sat} - F_B}{V}$$

$$= \frac{W_{sat} - \gamma_w \times V}{V}$$

$$= \frac{W_{sat}}{V} - \frac{\gamma_w \times V}{V}$$

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

$$\therefore \gamma' = \gamma_{sat} - \gamma_w$$

※ Unit weight of water :

γ_w = 9.81 kN/m^3 ≃ ~~10 kN~~ $/m^3$

(or)

ρ_w = 1 gm/cc   den = mass / volume

(or)

ρ_w = 1000 kg/m^3

$\gamma = \rho \cdot g$ (kN/m^3, gm/cm^3)

$g = 9.81$

$\gamma = 9.81 \times \rho$ (gm/cm^3)

5. Unit Weight Of Soil solids :

$$\gamma_s = \frac{W_s}{V_s} \quad kN/m^3$$

$$\gamma_s > \gamma_d$$

Overall comparison :

$$\gamma_s > \gamma_{sat} > \gamma_{bulk} > \gamma_{dry} > \gamma_{sub}$$

Based on Mass and Volume :

Density Of Soil : (ρ)

$$\rho = \frac{M}{V} \text{ in } g/cm^3 \text{ (or) } kg/m^3$$

1. Bulk density :

$$\rho_{bulk} = \frac{M}{V} \quad kg/m^3$$

2. Dry density :

$$\rho_{dry} = \frac{M_{dry} \text{ (or) } M_{solid}}{V} \quad kg/m^3$$

3. Density Of Solids :

$$\rho_{solid} = \frac{M_{solid}}{V_{solid}} \quad kg/m^3$$

4. Saturated density :

$$\rho_{sat} = \frac{M_{sat}}{V} \quad kg/m^3$$

In termes of 'ρ' :

$$I_D \text{ (or) } R.D = \frac{\rho_{d(nat)} - \rho_{d(min)}}{\rho_{d(max)} - \rho_{d(min)}} \times \frac{\rho_{d(max)}}{\rho_{d(nat)}} \times 100$$

(7)

where, $\rho_{d(nat)}$ = Dry density nature (correct) state of soil.

$\rho_{d(max)}$ = Dry density loose state of soil.

$\rho_{d(min)}$ = Dry density dense state of soil.

Case : 1

If the existing soil in nature, it very loose then,

$\boxed{\rho_{nat} = \rho_{max}}$ and hence

$$I_D = \frac{\rho_{max} - \rho_{nat}}{\rho_{max} - \rho_{min}} \times 100$$

$\therefore \boxed{I_D = 0}$

Case : 2

If the existing soil in nature, it very dense then, $\boxed{\rho_{nat} = \rho_{min}}$ and hence

$$I_D = \frac{\rho_{max} - \rho_{nat}}{\rho_{max} - \rho_{min}} \times 100$$

$\therefore \boxed{I_D = 0}$

Functional Relationship:

1. Relation b/w Void ratio (e) & Porosity (n):

$$n = \frac{e}{1+e}$$

$$n(1+e) = e$$

$$n + ne = e$$

$$n = e - ne$$

$$n = e(1-n)$$

$$\therefore \; e = \frac{n}{1-n}$$

2. Relation between n_a, n and a_c:

$$n_a = n \cdot a_c$$

3. Relation between Void ratio (e), specific gravity (G_s or G), Water content (w) and Degree of saturation (S_r):

By definition, $G_s = \frac{\gamma_s}{\gamma_w}$ Here, $\gamma_s = \frac{W_s}{V_s}$, $\gamma_w = \frac{W_w}{V_w}$

$$= \frac{\frac{W_s}{V_s}}{\frac{W_w}{V_w}}$$

$$= \frac{W_s}{V_s} \times \frac{V_w}{W_w}$$

$$= \frac{W_s}{W_w} \times \frac{V_w}{V_s}$$

(xly and ÷) by V_r

$$G_s = \frac{W_s}{W_w} \times \frac{V_w}{V_s} \times \frac{V_v}{V_v}$$

$$= \frac{W_s}{W_w} \times \frac{V_w}{V_v} \times \frac{V_v}{V_s}$$

By def.

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

$$S_r = \frac{V_w}{V_v}$$

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

$$G_s = \frac{1}{w} \times e \times S_r$$

$$\therefore \boxed{wG_s = eS_r}$$

If fully saturated,

$$wG_s = eS_r \qquad S_r = 100\%$$

$$wG_s = e \times 1$$

$$\therefore \boxed{e = wG_s}$$

4. Relation between dry unit weight (γ_d), Specific gravity (G_s) and Void ratio (e):

By definition, $\gamma_d = \frac{W_s \text{ (or) } W_d}{V}$

$$V = V_s + V_w + V_a$$

$$= V_s + V_v$$

$$V_v = V_w + V_a$$

$$= \frac{W_s}{V_v + V_s}$$

$$= \frac{W_s}{V_s\left[1 + \frac{V_v}{V_s}\right]} \qquad \because e = \frac{V_v}{V_s}$$

$$= \frac{W_s}{V_s(1+e)} \qquad \because \gamma_s = \frac{W_s}{V_s}$$

$$\gamma_{bulk} = \frac{W_s(1+W)}{V_s(1+e)}$$

By def, $W = \frac{W_w}{W_s}$, $e = \frac{V_v}{V_s}$

$$= \gamma_s \frac{(1+W)}{(1+e)}$$

$\because G_s = \frac{\gamma_s}{\gamma_w}$

$$\therefore \gamma_{bulk} = \frac{G_s \gamma_w (1+W)}{(1+e)}$$

(or)

$$\therefore (1+e)\gamma_{bulk} = G_s \gamma_w (1+w)$$

6. Relation between γ_{bulk}, G_s, e and S_r:

$$\gamma_{bulk} = \frac{G_s \gamma_w (1+w)}{(1+e)}$$

WKT,

$W G_s = e S_r$

$W = \frac{e S_r}{G_s}$

$$= \frac{G_s \gamma_w \left[1 + \frac{S_r e}{G_s}\right]}{(1+e)}$$

$$= \frac{G_s \gamma_w \left[\frac{G_s + S_r e}{G_s}\right]}{(1+e)}$$

$$\therefore \gamma_{bulk} = \frac{\gamma_w (G_s + S_r e)}{(1+e)}$$

7. Relation between γ_d, γ_{bulk} and W :

$$\gamma_d = \frac{G_s \gamma_w}{(1+e)}$$

We know that

$$\gamma_{bulk} = \frac{G_s \gamma_w (1+w)}{(1+e)}$$

$$\frac{G_s \gamma_w}{(1+e)} = \frac{\gamma_{bulk}}{(1+w)}$$

$$\therefore \gamma_d = \frac{\gamma_{bulk}}{(1+w)}$$

$$\gamma_{dry} = \frac{\gamma_w (G+es)}{1+e}$$

$$\gamma_d = \frac{\gamma_w G}{1+e}$$

$$\gamma_{sat} = \frac{\gamma_w (G+e)}{1+e}$$

1) Cons
2) Density
3) E.S
4) Sei

n, e

05/01/13

Problems:

1. If the porosity of the soil sample is 20%. Determine the void ratio.

2m

Given:

$n = 20\%$

$n = 0.2$

$e = ?$

Formula:

$$e = \frac{n}{1-n}$$

Solution:

$$e = \frac{0.2}{1-0.2}$$

$$= \frac{0.2}{0.8}$$

$$\therefore \boxed{e = 0.25}$$

2. The void ratio at the denses, loosest and natural states of a sand deposits are 0.2, 0.6, 0.4 respectively. Determine relative density.

2m

Given:

$e_{max} = 0.6$ (loosest)

$e_{min} = 0.2$ (denses)

$e_{nat} = 0.4$ (natural)

I_D (or) R.D = ?

Solution :

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

$$= \frac{0.6 - 0.4}{0.6 - 0.2} \times 100$$

$$= \frac{0.2}{0.4} \times 100$$

$$= 0.5 \times 100$$

$$\therefore I_D = 50\%$$

3. A soil sample as a porosity of 40% and the specific gravity of soil solid is 2.70. Calculate 1) Void ratio ; 2) Dry density ; 3) Unit weight if the soil is 50% Saturated ; 4) Unit weight if the soil is fully saturated.

8m 11(b)

Given:

$n = 40\% = 0.4$

$G_s = 2.70$

To find :

1. Void ratio (e)
2. Dry density (ρ_d)
3. Unit wt. of soil (γ) [50% Saturated]
4. Unit wt. of soil (γ) [fully Saturated]

Solution :

1. Void ratio :

$$e = \frac{n}{1-n}$$

$$= \frac{0.4}{1-0.4}$$

$$\therefore e = 0.67$$

2. Dry density :

$$\rho_d = \frac{G_s \rho_w}{1+e}$$

$$= \frac{2.70 \times 1}{1+0.67} \qquad \because \rho_w = 1 g/cc$$

$$\rho_d = 1.676 \ g/cc$$

3. Unit weight of Soil : $[S_r = 50\% = 0.5]$

$$\gamma = \frac{(G_s + S_r e)\gamma_w}{(1+e)}$$

$$= \frac{(2.70 + (0.5 \times 0.67))9.81}{1+0.67}$$

$$\therefore \gamma = 17.82 \ kN/m^3$$

4. Unit weight of Soil : $[S_r = 100\% = 1]$

$$\gamma = \frac{(G_s + S_r e)\gamma_w}{1+e}$$

$$= \frac{(2.70 + (1 \times 0.67)) \times 9.81}{1 + 0.67}$$

$$= \frac{33.0597}{1.67}$$

$$\therefore \gamma = 19.79 \text{ kN/m}^3$$

4. A soil has a bulk density of 1.9 g/cc and a water content 9.5%, specific gravity of soil solid 2.65. Find the porosity of soil.

Given :

$\rho_{bulk} = 1.9$ g/cc

$w = 9.5\%$

$G_s = 2.65$

$$\gamma = \frac{(G_s + S_r e)\gamma_w}{1+e}$$

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

$$\gamma = \frac{(G_s + S_r e)\gamma_w}{1+e}$$

To find:

Porosity (n)

Solution :

$$\rho_{bulk} = \frac{G_s \rho_w (1+w)}{1+e}$$

$$1+e = \frac{G_s \rho_w (1+w)}{\rho_{bulk}}$$

$$1+e = \frac{2.65 \times 1 \left(1+\frac{9.5}{100}\right)}{1.9}$$

$$= \frac{2.65\,(1+0.095)}{1.9}$$

$$\boxed{1+e = 1.527}$$

$$e = 1.527 - 1$$

$$\therefore \boxed{e = 0.527}$$

WKT,

$$\boxed{n = \frac{e}{1+e}}$$

$$= \frac{0.527}{1.527}$$

$$= 0.345$$

$$\therefore \boxed{n = 34.5\,\%}$$

5. The total unit weight of soil is 18.8 kN/m³ and the specific gravity of soil particles is 2.67 and the water content of soil is 12 % Calculate

1. Dry unit weight
2. Void ratio
3. Degree of saturation

Given:

$\gamma = 18.8 \text{ kN/m}^3$

$G_s = 2.67$

$w = 12\% = 0.12$

To find:

1. Dry unit weight (γ_d)
2. Void ratio (e)
3. Degree of saturation (S_r)

Solution:

Dry unit weight (γ_d):

$$\boxed{\gamma_d = \frac{\gamma}{1+w}}$$

$$= \frac{18.8}{1+0.12}$$

$$\therefore \boxed{\gamma_d = 16.78 \text{ kN/m}^3}$$

Void ratio (e):

$$\boxed{e = \frac{G_s \gamma_w}{\gamma_d} - 1}$$

$$= \frac{2.67 \times 9.81}{16.78} - 1$$

$$= 1.5609 - 1$$

$$\therefore \boxed{e = 0.56}$$

Degree of Saturation (S_r):

$$S_r = \frac{W G_s}{e}$$

$$= \frac{0.12 \times 2.67}{0.56}$$

$$= 0.5721$$

$$\therefore S_r = 57.21\%$$

6. A sample of sand has natural moisture content 15% and unit weight of sand is 18.84 kN/m^3 and max void ratio is 0.85 and min void ratio is 0.5. Compute
   1. Degree of saturation
   2. Relative density, Take $G_s = 2.65$

Given:

$W = 15\% = 0.15$

$\gamma = 18.84 \ kN/m^3$ $\quad \gamma = \gamma_{bulk}$

$e_{max} = 0.85$

$e_{min} = 0.5$

$G_s = 2.65$

To find:

1. Degree of saturation (S_r)
2. Relative density (I_D)

Solution:

$$\boxed{w G_s = e S_r}$$

$$e = \frac{0.15 \times 2.65}{S_r}$$

$$e = \frac{0.3975}{S_r} \rightarrow (1)$$

$$\boxed{\gamma = \frac{G_s \gamma_w (1+w)}{(1+e)}}$$

$$\gamma = \frac{G_s \gamma_w (1+w)}{(1+e)}$$

$$1+e = \frac{G_s \gamma_w (1+w)}{\gamma}$$

$$1+e = \frac{2.65 \times 9.81 (1+0.15)}{18.84}$$

$$1+e = 1.586$$

$$e = 1.586 - 1$$

$$\therefore \boxed{e = 0.586}$$

From (1), $S_r = \frac{0.3975}{e}$

$$= \frac{0.3975}{0.586}$$

$$= 0.6783$$

$$\therefore \boxed{S_r = 67.83\%}$$

To find :

1. Degree of Saturation (S_r)
2. Void ratio (e)

Solution :

Void ratio :

$$\gamma = \frac{G_s \rho_w (1+w)}{(1+e)}$$

$$1+e = \frac{G_s \rho_w (1+w)}{\rho_{bulk}}$$

$$= \frac{2.65 \times 1 (1+0.22)}{2}$$

$$1+e = 1.6165$$

$$e = 1.6165 - 1$$

$$\therefore e = 0.6165$$

Degree of Saturation:

$$w G_s = e S_r$$

$$S_r = \frac{w G_s}{e}$$

$$S_r = \frac{0.22 \times 2.65}{0.6165}$$

$$= \frac{0.5830}{0.6165}$$

$$= 0.9457$$

$$\therefore \boxed{S_r = 94.57\,\%}$$

8. A soil has been compacted in embankment at a bulk density of 2.15 mg/m³ and water content is 12% and the value of specific gravity of soil is 2.65. The water table is well below the foundation level. Estimate, 1. Dry density; 2. Degree of saturation; 3. Void ratio; 4. Porosity 5. Air content; 6. % Air Voids.

$1\,mg/m^3 = 1\,g/cm^3$

CC - Cubic Centimeter

Given:

$$\rho_{bulk} = 2.15\ mg/m^3$$

$$= 2.15\ g/cm^3$$

$$w = 12\% = 0.12$$

$$G_s = 2.65$$

To find:

1. Dry density (ρ_d)
2. Degree of saturation (S_r)
3. Void ratio (e)
4. Air Content (a_c)
5. Porosity (n)
6. % Air Voids (n_a)

Solution:

Dry density:

$$\rho_{bulk} = \frac{G_s \rho_w (1+w)}{1+e}$$

$$1+e = \frac{2.65 \times 1 (1+0.12)}{2.15}$$

$$1+e = 1.3804$$

$$\therefore e = 0.3804$$

$$\rho_d = \frac{G_s \rho_w}{1+e}$$

$$= \frac{2.65 \times 1}{1+0.3804}$$

$$= \frac{2.65}{1.3804}$$

$$\therefore \rho_d = 1.919 \; g/cc$$

$$\boxed{w G_s = e S_r}$$

$$S_r = \frac{w G_s}{e}$$

$$= \frac{0.12 \times 2.65}{0.3804}$$

$$= 0.8359$$

$$\therefore \boxed{S_r = 83.59\ \%}$$

$$\boxed{a_c = 1 - S_r}$$

$$= 1 - 0.8359$$

$$\therefore \boxed{a_c = 0.164} \quad \therefore a_c = 16.4\%$$

$$\boxed{n = \frac{e}{1+e}}$$

$$= \frac{0.3804}{1+0.3804}$$

$$= 0.2755$$

$$\therefore \boxed{n = 27.55\%}$$

$$\boxed{n_a = a_c \cdot n}$$

$$= 0.164 \times 0.2755$$

$$= 0.046$$

$$= 0.05$$

$$\therefore \boxed{n_a = 5\%}$$

9. The unit weight of moist soil 16.5 kN/m³. water Content is 15% and specific gravity is 2.7. Determine γ_d, n, s and mass of water.

Given:

$w = 15\% = 0.15$

$G_s = 2.7$

$\gamma = 16.5 \; kN/m^3$

To find:

1. Dry unit weight (γ_d)
2. Porosity (n)
3. Degree of Saturation (S_r)
4. Mass of water

Solution:

$$\gamma_d = \frac{\gamma}{1+w}$$

$$= \frac{16.5}{1+0.15}$$

$$\gamma_d = 14.35 \; kN/m^3$$

$$\gamma_d = \frac{G\gamma_w}{1+e}$$

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

$$\gamma_d = \frac{\gamma}{1+w}$$

$$\gamma_d = \frac{G\gamma_w}{1+e}$$

$$e = \frac{2.7 \times 9.81}{14.35} - 1$$

$$e = ~~17.46~~ \; 0.846$$

$$n = \frac{e}{1+e} = \frac{0.846}{1+0.846} = 0.458 = 45.8\%$$

$$= \frac{17.46}{1+17.46}$$

$$= 0.946$$

$$n = 94.6\%$$

$$wG = eS_r$$

$$S_r = \frac{wG}{e}$$

$$= \frac{0.15 \times 2.7}{~~17.46~~ \; 0.846}$$

$$= 0.4787$$

$$= 47.87\%$$

07/01/13

Determination Of Index Properties:

Index properties of

1. water content
2. Specific gravity
3. Particle (Grain) Size distribution
4. Consistency limits
5. In-situ density & density index.

• It is used to find out the identification and classification of soils.

Method to determine water content:

*16M 1. Oven drying method
2. Sand bath method
3. Pycnometer method

Other methods:

1. Alcohol method
2. Calcium
3. Radiation method
4. Torsion balance method

1. Oven drying method: (Lab method)

* It is the accurate method of determining the water content.

* To find the weight of the empty container = w_1 (gms).

* To find the weight of the empty container + wet soil = W_2 (gms)
* To find the weight of the wet soil = $W_2 - W_1$ (gms)
* Keep the wet soil in the oven for 24 hours at a temperature of 110°c and on the next day only soil solids are present.

i.e., weight of dry solids + container = W_3 (gms)

- weight of solids = $W_3 - W_1$ (gms)
- weight of water = $W_2 - W_3$ (gms)

To find the water content

$$w = \frac{W_2 - W_3}{W_3 - W_1} \text{ (or) } \frac{W_w}{W_s}$$

Note: For organic soil temperature shall not exceed 60°c.

For soil containing gypsm, the temperature shall not exceed 80°c.

2. Sand bath method :

* It is the field method to determining the water content.
* A sand bath is a large open vessel containing sand filled to a depth 3cm.
* The soil sample is taken in a tray and few piece of water paper are also placed on the tray, the tray is weighed and the mass of the wet sample is obtained.
* The tray is then placed on sand bath and sand bath is heated over a kerosene stove.
* During heating process the specimen is turned with Palette Knife.
* The white paper turns brown when over heating occurs.
* When drying is complete, till the sample attain a constant mass, then the tray is removed from the sand bath, then cooled and weighed, then the water content is determined.

Disadvantage:

- This method is not used for Organic soil and soil having high % of gypsum.

※ Pycnometer Method:

$$\text{Water content } (w) = \left[\frac{w_2 - w_1}{w_3 - w_4} \times \frac{G_s - 1}{G_s} - 1\right] \times 100$$

where, w_1 = Empty weight of pycnometer

w_2 = Weight of pycnometer + wet soil

w_3 = pycnometer weight + dry soil

w_4 = weight of pycnometer + water

G = Specific gravity of soil

$$\text{Specific Gravity } (G) = \frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)}$$

* Take pycnometer glass tube of 900 ml capacity and take the weight of the empty glass tube.
* Fill the glass tube with 200ml to 400ml of sand and take the weight.
* Add water into the glass tube and keep it in the oven and then take the weight after it is dried.
* Add freshwater into the glass tube and take the weight.

09/01/13

Particle Size distribution:

The percentage of Various size of particle in a given dry soil sample is found by a particle size analysis or mechanical analysis.

It performed in 2 stages.

1. Sieve analysis → Coarse grained soil
2. Sedimentation analysis (or) wet mechanical analysis → Fine grain soil

Coarse grained soil: $[> 75\,\mu]$

example: $1\,\mu = 10^{-3}$ mm

Boulders = 7300mm

cobbles = [75 - 300 mm]

Gravels = [4.75mm - 75mm]

Sand = [75μ - 4.75mm]

Fine grained soil: $[< 75\,\mu]$

example:

Silt = [0.002mm to 0.075mm]

clay = $[< 0.002\text{mm}]$

The following sieves used for Coarse analysis are,

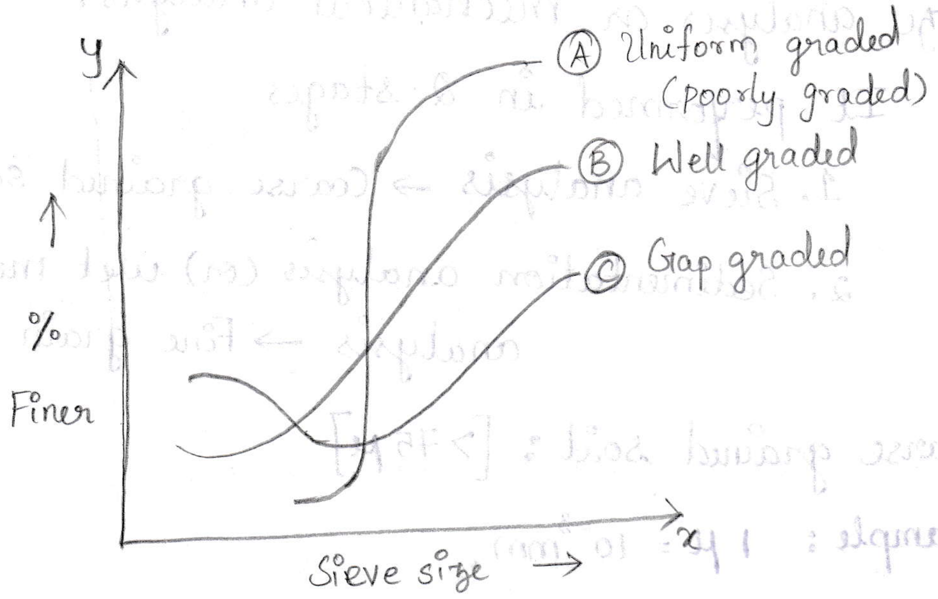
IS = 100mm, 63, 20 & 10, 4.75mm

for Fine sieve analysis are,

IS = 2mm, 1.0mm, 600μ, 425μ, 300μ, 212 & 75μ

Particle size distribution Curve:

It gives idea about the type and gradation of the soil. **Mr. Hazen**



Uniform Graded:

→ Soil posses same dia of particle.

Well graded:

→ Good representation of all size and vary from gravel to clay.

Gap graded:

→ Some of the sizes of particles missing.

According to Mr. Hazen, a material which is poorly graded or well graded can be determined with help of equation, uniformity cohesion (or) coefficient of uniformity (C_u).

$$C_u = \frac{D_{60}}{D_{10}}$$

where,

D_{60} - Dia of particle at 60% finer.

D_{10} - Dia of particle at 10% finer.

If,

$C_u < 5$ ⇒ Soil will be uniformly graded.

$C_u = 5$ to 15 ⇒ Soil will be medium graded.

$C_u > 15$ ⇒ Soil will be well graded.

From the graph,

Coefficient of curvature $(C_c) = \dfrac{D_{30}^2}{D_{60} \cdot D_{10}}$

where, D_{30} = Size of particle at 30% fine.

C_c lie between 1 and 3, Soil will be well graded.

Sedimentation analysis:

→ Based on stoke's law

→ To find size of particle < 75μ

Assume,

Soil spherical shape

G → Same

According to stoke, if a single sphere is allowed to fall through a liquid of indefinite extent the terminal velocity can be expressed as:

$$V \propto (\gamma_s - \gamma_w)$$

$$\propto D^2$$

$$\propto \frac{1}{\mu}$$

$$V \propto \frac{(\gamma_s - \gamma_w) D^2}{\mu} \qquad \gamma_s = G_s \gamma_w$$

$$V = \frac{1}{18} \left[\frac{(G_s \gamma_w - \gamma_w) D^2}{\mu} \right]$$

$$V = \frac{H}{t} = \frac{\gamma_w [G_s - 1] D^2}{18\mu}$$

where,

H = Depth of settle of soil in m.

t = Time of settle of soil in sec.

γ_w = Unit weight of water (kN/m^3)

G_s = Specific gravity of soil

D = Diameter of soil grain in m

μ = Coefficient of Dynamic viscosity

PROBLEMS:

10. Determine time required to settle a soil grain having size 0.4mm, through depth of water 6m high. Take $G_s = 2.65$ and μ is 0.015 poise.

Solution:

Given: $D = 0.4mm = 0.4 \times 10^{-3}$ m

$H = 6m$

$G_s = 2.65$

$\mu = 0.015$ poise $= \frac{0.015}{10 \times 1000}$ kN sec/m^2

$$\frac{H}{t} = \frac{\gamma_w [G_s - 1] D^2}{18\mu}$$

$$t = \frac{18 \mu H}{\gamma_w [G_s - 1] D^2}$$

$$= \frac{18 \times 0.015 \times 10^{-4} \times 6}{9.81 [2.65 - 1] (0.4 \times 10^{-3})^2}$$

Consistency limit or Atterberg's limit :

* Fine grained soil
* Degree of firmness of soil

- Consistency limit is used for fine grained soil. It is the degree of firmness of soil.
- The water content at which the soil changes from one state to another state is called consistency limit or Atterberg's limit.
- Depending upon the consistency the soil is indicated by soft, medium and stiff or hard.
- When water is added to fine grained soil, the soil can be made of a paste, and further addition of water, reduce the cohesion of soil i.e., the soil will be under suspension.
- It consists of four types :

1. Liquid Limit
2. Plastic Limit
3. Semi solid limit } Shrinkage Limit
4. Solid limit

Liquid Limit (W_L):

- It is the arbitrary water content between the liquid and plastic limit.
- It is formed by case grande apparatus.

Plastic Limit (W_P):

- It is the arbitrary water content between plastic and semi-solid state.

Shrinkage Limit: (W_S)

- It is the minimum water content at which the soil is saturated.

Plasticity Index (I_P):

- It is the difference between liquid limit and plastic limit.

$$I_P = W_L - W_P$$

Consistency Index (C_I):

It is defined as the ratio of difference between liquid limit and natural water content to the plasticity index.

$$C_I = \frac{W_L - W_n}{I_P}$$

Note:-

1. when the, $W_n = W_P$

then, $C_I = 1$ (100%)

Soil is strong

2. When $w_n = w_L$

$C_I = 0$ (soil is weak)

Liquidity Index (L_I) :

It is defined as the ratio of difference between natural water content and plastic limit to the plasticity index.

$$L_I = \frac{w_n - w_p}{I_p}$$

Note :

1. when, $w_n = w_p$

$L_I = 1$ (soil is weak)

2. when, $w_n = w_p$

$L_I = 0$ (soil is strong)

11. The classification test conducted on two samples yield at the following results.

Soil	W_L	W_p	W_n
Soil A	63%	30%	60%
Soil B	50%	30%	35%

Write down statement

1. which soil has high degree of plasticity.
2. which soil is stronger.

Solution:

Soil A : 1. Plasticity Index (I_p) $= W_L - W_p$

$= 63 - 30$

$\therefore I_p = 33\%$

2. Consistency Index (C_I) $= \frac{W_L - W_n}{I_p}$

$= \frac{63 - 60}{33}$

$\therefore C_I = 0.09 \simeq 9\%$

3. Liquidity Index :

$$L_I = \frac{w_n - w_p}{I_p}$$

$$= \frac{60 - 30}{33}$$

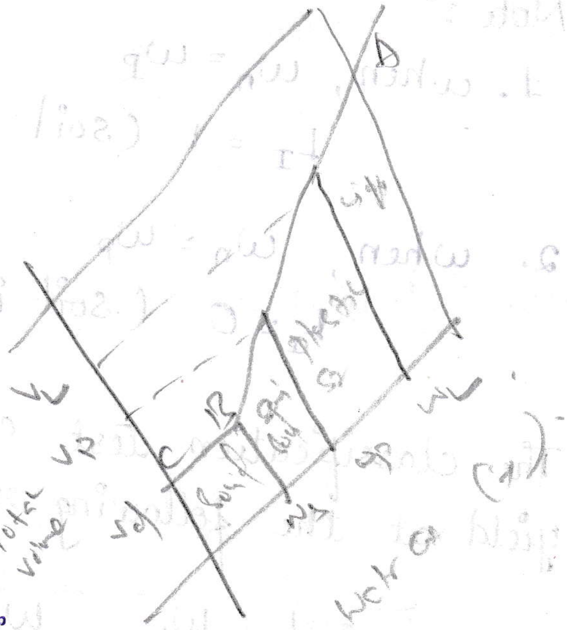
$$\therefore L_I = 0.9 \simeq 90\%$$

Soil B :

1. $I_p = W_L - W_p$

$$= 50 - 30$$

$$I_p = 20\%$$



2. $C_I = \frac{W_L - W_n}{I_p}$

$$= \frac{50 - 35}{20}$$

$$\therefore C_I = 0.75 \simeq 75\%$$

3. $L_I = \frac{W_n - W_p}{I_p}$

$$= \frac{35 - 30}{20}$$

$$\therefore L_I = 0.25 \simeq 25\%$$

Result :

- Soil A has high degree of plasticity
- Soil B is strong

11/01/13

Classification of Soil:

- It is based on Engineering Properties.
- It is used for construction of dams, bridges, etc.

Classification of soil system:

- Based on particle size distribution
- Textural classification system based on % of particle distribution
- Unified soil classification system and I_s C/s system.

Based on particle size distribution:

↳ Clay, Silt, sand and gravel

↳ Soild grain soil.

Sub C/s System:

1. USB Soil (United State Bureau of Soil) and Public Road Administration (PRA).
2. MIT C/s System
3. I_s C/s System

USBureau of Soil and PRA C/s System:

1. Soil < 0.005 mm → clay.
2. Soil with 0.005 to 0.05 mm → Silt
3. Soil with 0.05 mm to 1 mm → Sand
   - 0.05 to 0.1 mm — Very fine Sand
   - 0.1 to 0.25 mm — Fine Sand
   - 0.25 - 0.5 mm — Medium Sand
   - 0.5 - 1 mm — Coarse Sand
4. Soil Consist 1 mm to 2 mm → Fine gravel

→ Gravel

MIT C/s System :

1. Soil < 0.002 mm → clay
2. Soil with 0.002mm – 0.06mm → Slit

   - 0.002–0.006mm — Fine Slit
   - 0.006–0.02mm — Medium slit
   - 0.02–0.06mm — Coarse Slit

3. Soil with 0.06 to 2mm → Sand

   - 0.06–0.2mm — Fine Sand
   - 0.2–0.6mm — Medium Sand
   - 0.6–2mm — Coarse Sand

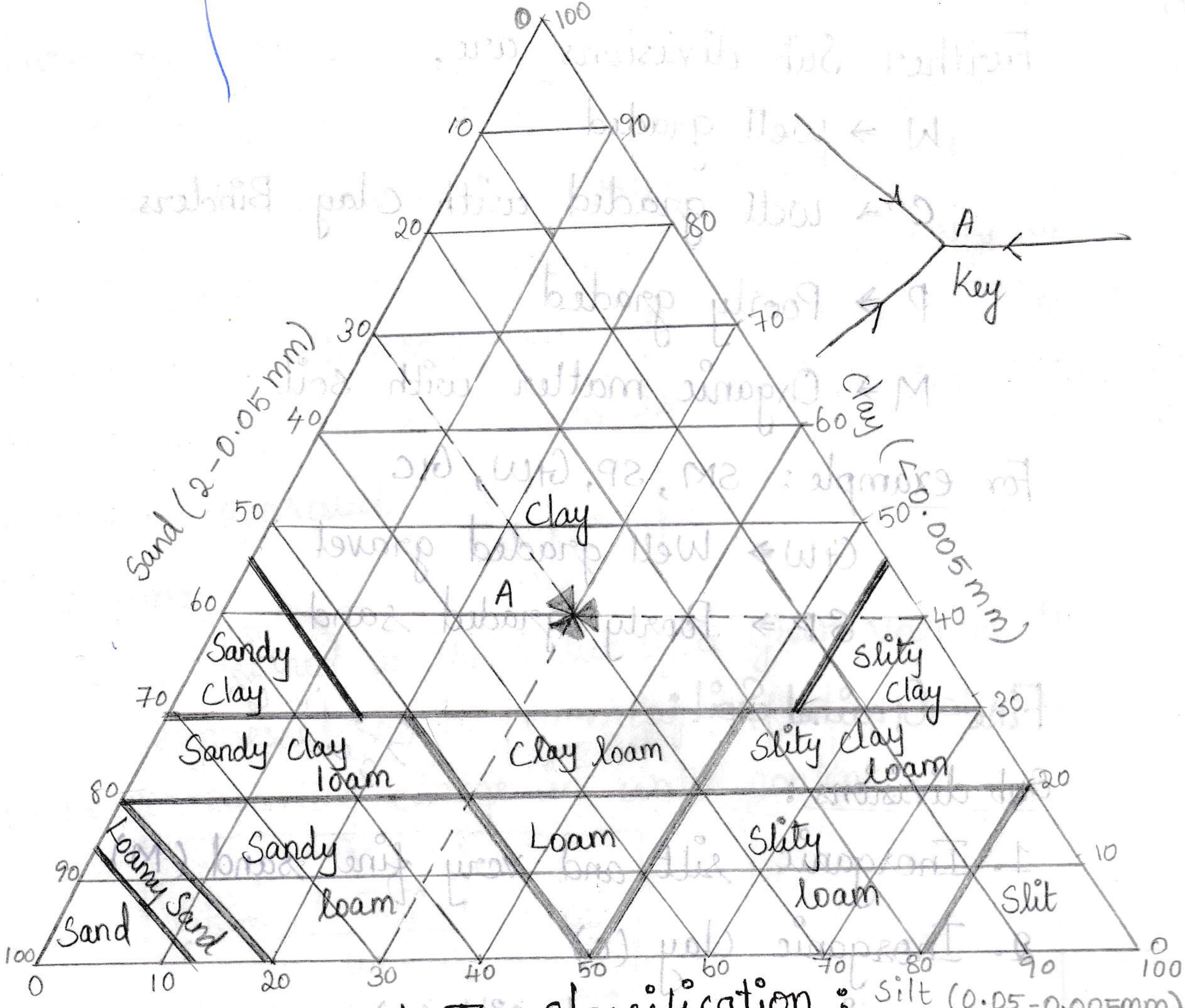
4. Soil > 2mm → gravel.

Textural C/s System :

1. Sand → 0.05 to 0.2 mm
2. Slit → 0.005 to 0.05mm
3. Clay → < 0.005 mm

Textural Classification Chart

(Adapted from U.S Public Roads Administration)



Unified Soil and I_s Classification :

* The soils are classified into three major graups such as
  - ↳ Coarse grain Soil
  - ↳ Fine grain soil
  - ↳ Highly grain soil

1. Coarse grain soil -> 75 μ I_s Sieve
2. Fine grain Soil - < 75μ I_s Sieve
3. Highly grain Soil - Large % of fibre and organic matter

Coarse Grained Soil :

Sub division :

1. Gravel → > 4.75mm I_s Sieve
2. Sand → < 4.75 mm I_s Sieve

Further Sub divisions are,

W → well graded

C → well graded with clay Binders

P → Poorly graded

M → Organic matter with soil

For example: SM, SP, GW, GC

GW → Well graded gravel

SP → Poorly graded sand

Fine Grained Soil:

Sub divisions:

1. Inorganic silt and very fine sand (M)
2. Inorganic clay (C)
3. Organic clays and Silt (O)

Further Sub divisions are,

1. Silt and clay of low compressibility → $W_L < 35\%$ [L]
2. Silt and Clay of medium compressibility → $W_L > 35 < 50$ [I]
3. Silt and clay of high compressibility → $W_L < 50$ [H]

For example:

CI → Inorganic clay with low compressibility

MH → Inorganic slit with high Compressibility

Shrinkage ratio:

We have seen that if a soil slurry is allowed to dry up, the reduction in water content of the saturated soil mass is accompained by a change in the volume of the soil mass, the total change in the volume of the soil mass is equal to the volume of water evaporated.

Definition:

* It is defined as the ratio of a given volume change expressed as a percentage of dry volume, to the corresponding change in water content.

$$SR = \frac{\left(\frac{V_1 - V_2}{V_d}\right)}{w_1 - w_2} \times 100$$

where, V_1 = Volume of soil mass at water content w_1.

(d) V_2 = Volume of soil mass at water content w_2.

V_d = Volume of dry soil mass.

w_1, w_2 = water content.

* It is expressed as percentage.

Volumetric Shrinkage: (V_S)

It is defined as the ratio of change in volume expressed as a % dry volume of the soil mass, when the water content is reduced from a given shrinkage limit.

$$V_s = \frac{V_1 - V_d}{V_d} \times 100$$

Linear Shrinkage:

It is defined as the decrease in one dimension of a soil mass expressed as a % of original dimension, with water content is reduced from a given value to the shrinkage limit.

$$L_s = 100\left[1 - \left(\frac{100}{V_s + 100}\right)^{1/3}\right]$$

Consistency limit formula:

1. Shrinkage limit:

$$W_s = \frac{(W_{wet} - W_{dry}) - (V_{wet} - V_{dry})\gamma_w}{W_{dry}}$$

$$W_L = \frac{W_{wet} - W_{dry}}{W_{dry}}$$

$$W_s = W_L - \left[\frac{(V_{wet} - V_{dry})\gamma_w}{W_{dry}}\right]$$

$$SR = \frac{W_{dry}}{V_{dry}} \cdot \gamma_w \qquad (\gamma) \quad \frac{\gamma}{\gamma_w}$$

$$W_s = \frac{1}{SR} - \frac{1}{G}$$

$$W_s = M - \left[\frac{(V_{wet} - V_{dry})\rho_w}{M_{dry}}\right]$$

Deg. of Shrinkage
<5
5-10
10-15

>> Soil quality
Good
Medium
Poor

Note:

1. For liquid limit and plastic limit the volume is taken as $\boxed{V_{wet}}$.

2. For Shrinkage limit the volume is taken as $\boxed{V_{dry}}$.

Flow Index (I_f):

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

where, W_1 = water content corresponding to blows N_1

W_2 = water content corresponding to blows N_2

Toughness Index (I_t):

$$I_t = \frac{I_P}{I_f} = \frac{\text{Plasticity Index}}{\text{Flow Index}}$$

It is used to measure shearing strength of soil at plastic limit.

12. The atterberg limit of a clay are liquid limit is 52%, Plastic limit is 30% and shrinkage limit is 30%. If the specimen of the soil shrinks from a volume of $39.55 cm^3$ of liquid limit to a volume of $24.2 cm^3$ at shrinkage limit. Calculate G.

Given:

$W_L = 52\%$

$W_P = 30\%$

$W_S = 18\%$

Volume at $W_L = 39.55\ cm^3\ (V_{wet})$

$W_S = 24.2\ cm^3\ (V_{dry})$

Take, $\rho_w = 1 g/cm^3$

Take γ_w as a ρ_w

13. The following index properties where determine for two soils A and B.

Index Properties	Soil A	Soil B
Liquid Limit (w_L)	65	35
plastic limit (w_p)	25	20
water content (w)	35%	25%
Sp. gravity of Soil (G_s)	2.7	2.65
Degree of Saturation (S_r)	100%	100%

Which of the soil as,

1. Contain more clay particles 2. has a greatest bulk density 3. has greatest dry density 4. has a greatest Void ratio.

Solution:

Properties	Soil A	Soil B	Remarks
1. Plasticity Index: $I_p = W_L - W_p$	$= 65 - 25$ $= 40\%$	$= 35 - 20$ $= 15\%$	Soil A has more clay particles
2. Void ratio: $e = \frac{WG}{S}$	$= \frac{0.3 \times 2.7}{1}$ $= 0.945$	$= \frac{0.25 \times 2.65}{1}$ $= 0.66$	Soil A has greater void ratio
3. Dry density: $\rho_d = \frac{G\rho_w}{1+e}$	$= \frac{2.7 \times 1}{1+0.945} = 1.388 \, g/cm^3$	$= \frac{2.67 \times 1}{1+0.66} = 1.608 \, g/cm^3$	Soil B has greater ρ_d
4. Bulk density: $\rho = \rho_d(1+w)$	$= 1.388(1+0.35)$ $= 1.87 \, g/cm^3$	$= 1.608(1+0.25)$ $= 2.01 \, g/cm^3$	Soil B has greater ρ

Result:

More clay particles : Soil A

Greater Void ratio : Soil A

Greater Dry density : Soil B

Greater Bulk density : Soil B

Solution :

$$W_s = W_L - \left[\frac{V_{wet} - V_{dry}}{W_{dry}} \cdot \rho_w \right]$$

$$0.18 = 0.52 - \frac{(39.5 - 24.2) \times 1}{W_{dry}}$$

$$0.18 - 0.52 = - \frac{15.3}{W_{dry}}$$

$$W_{dry} = \frac{-15.3}{-0.34}$$

$$\therefore W_{dry} = 45 \text{ gram}$$

Shrinkage ratio :

$$R = \frac{W_{dry}}{V_{dry} \cdot \rho_w}$$

$$= \frac{45}{24.2 \times 1}$$

$$\therefore \boxed{R = 1.859}$$

$$W_s = \frac{1}{R} - \frac{1}{G}$$

$$0.18 = \frac{1}{1.859} - \frac{1}{G}$$

$$-\frac{1}{G} = 0.18 - 0.54$$

$$-\frac{1}{G} = -0.36$$

$$\therefore \boxed{G = 2.85}$$

Result :

$$R = 1.859$$

$$G = 2.85$$

14. A soil has a liquid limit of 25% and flow index 12.5%. If the plastic limit is 15%. Determine the plasticity index and toughness index. If the water content of soil in ints. natural condition in the field is 20%. Find the Liquid index and relative consistency.

Given :

$W_L = 25\%$, $I_f = 12.5\%$, $W_p = 15\%$, Water content $(W_n) = 20\%$

To find :

I_p , I_t , L_I , C_I

Solution :

1. Plasticity Index :

$$\boxed{I_p = W_L - W_p} = 25 - 15 = 10\%$$

2. Toughness Index :

$$\boxed{I_t = \frac{I_p}{I_f}} = \frac{10}{12.5} = 0.8 \text{ (or) } 80\%$$

3. Liquid Index :

$$\boxed{L_I = \frac{W_n - W_p}{I_p}} = \frac{20-15}{10} = \frac{5}{10} = 0.5 \text{ or } 50\%$$

4. Consistency Index :

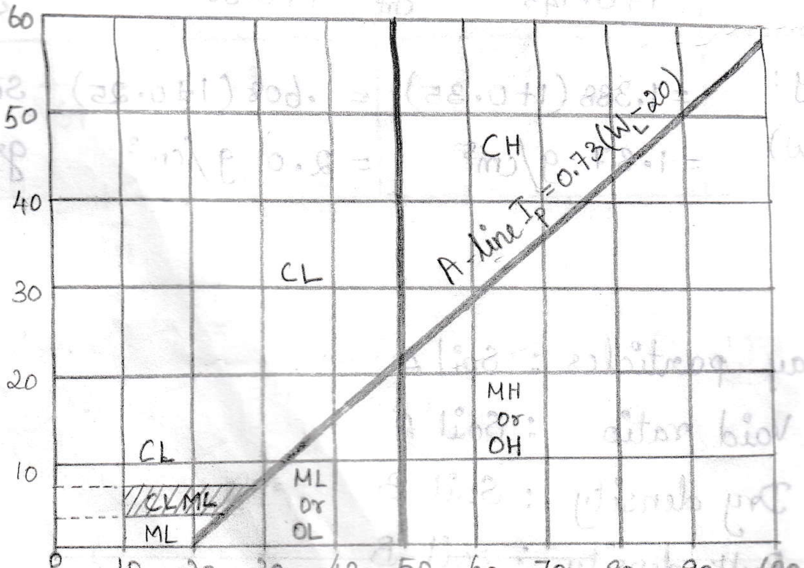
$$\boxed{C_I = \frac{W_L - W_n}{I_p}} = \frac{25-20}{10} = \frac{5}{10} = 0.5 \text{ or } 50\%$$

CLASSIFICATION OF SOILS :

Unified Soil and I_s Classification:

(%) for problem plasticity chart refer book page no: 117

Fine Grained Soil :



15. Classify the soil if the liquid limit is 40% and plastic limit is 22% by using plasticity chart.

Given:

$W_L = 40\%$; $W_p = 22\%$

To find:

Types of Soil → plasticity chart

Solution:

$I_p = W_L - W_p = 40 - 22$
$= 18\%$

Types of soil is CI.

16. Find the type of IF liquid limit 20% and plastic limit is 14%.

Given:

$W_L = 20\%$; $W_p = 14\%$

Solution:

$I_p = W_L - W_p = 20 - 14$
$= 6\%$

Type of soil is CL and ML

Is Classification of soil for coarse grained soil (Laboratary Classification criteria):

GROUP SYMBOLS	LABORATORY CLASSIFICATION CRITERIA
GW	$C_u > 4$, $1 < C_c < 3$
GP	Atterberg limits below A-line (or) $I_p < 4$
GC	Atterberg limits above A-line (or) $I_p > 7$
SW	$C_u > 6$, $1 < C_c < 3$
SP	Not meeting both criteria for SW
SM	Atterberg limits below A-line (or) $I_p < 4$
SC	Atterberg limits above A-line (or) $I_p > 7$
GP	Not meeting both criteria for GW

14. A soil has a liquid limit of 25% and flow index 12.5%. If the plastic limit is 15%. Determine the plasticity index and toughness index. If the water content of soil in ints. natural condition in the field is 20%. Find the Liquid index and relative consistency.

Given :

$W_L = 25\%$, $I_f = 12.5\%$, $W_p = 15\%$, Water content $= 20\%$ (W_n)

To find :

I_p, I_t, L_I, C_I

Solution :

1. Plasticity Index :

$$\boxed{I_p = W_L - W_p} = 25 - 15 = 10\%$$

2. Toughness Index :

$$\boxed{I_t = \frac{I_p}{I_f}} = \frac{10}{12.5} = 0.8 \text{ (or) } 80\%$$

3. Liquid Index :

$$\boxed{L_I = \frac{W_n - W_p}{I_p}} = \frac{20-15}{10} = \frac{5}{10} = 0.5 \text{ or } 50\%$$

4. Consistency Index :

$$\boxed{C_I = \frac{W_L - W_n}{I_p}} = \frac{25-20}{10} = \frac{5}{10} = 0.5 \text{ or } 50\%$$

CLASSIFICATION OF SOILS :

Unified Soil and I_s Classification:

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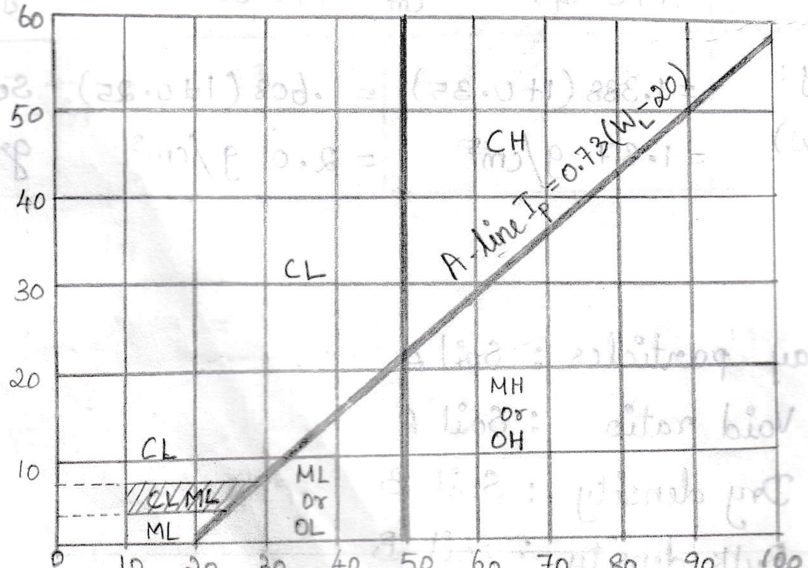
Fine Grained Soil :



15. Classify the soil if the liquid limit is 40% and plastic limit is 22% by using plasticity chart.

Given:

$W_L = 40\%$; $W_p = 22\%$

To find:

Types of Soil → plasticity chart

Solution:

$I_p = W_L - W_p = 40 - 22$

$= 18\%$

Types of soil is CI.

16. Find the type of IF liquid limit 20% and plastic limit is 14%

Given:

$W_L = 20\%$; $W_p = 14\%$

Solution:

$I_p = W_L - W_p = 20 - 14$

$= 6\%$

Type of soil is CL and ML

Is Classification of soil for coarse grained soil (Laboratary classification criteria):

GROUP SYMBOLS	LABORATARY CLASSIFICATION CRITERIA
GW	$C_u > 4$, $1 < C_c < 3$
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GC	Atterberg limits above A-line (or) $I_p > 7$
SW	$C_u > 6$, $1 < C_c < 3$
SP	Not meeting both criteria for SW
SM	Atterberg limits below A-line (or) $I_p < 4$
SC	Atterberg limits above A-line (or) $I_p > 7$
GP	Not meeting both criteria for GW

Depending upon fineness (passing through 75μ sieve)

$<5\%$ = GW, GP, SW, SP

$>12\%$ = GM, GC, SM, SC

5% to 12% = Border line cases requiring use of dual symbols.

$$C_u = \frac{D_{60}}{D_{10}}$$

where, C_u = Uniformity Co-efficient

$$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

where, C_c = Co-efficient of curvature

17. Find the type of soil if (i) passing 4.75mm sieve = 70% (ii) passing 75μ sieve = 8%, uniformity co-efficient = 7, Co-efficient of curvature = 3, plasticity index = 3%.

Given data:

Passing 4.75mm sieve = 70% (30% of soil is > 4.75mm is retained)

Passing 75μ sieve = 8% (Fineness)

$C_u = 7$, $C_c = 3$, $I_p = 3\%$

To find:

Type of soil

Solution:

Since, 70% of soil passes through 4.75mm sieve

⇒ Soil is termed as sand (S).

⇒ From $C_u = 7$, $C_c = 3$ [$C_u > 6$, C_c = B/w 1 to 3]

Soil is SW

⇒ Fineness = 8% [lies b/w 5% to 12% = Border line case]

⇒ $I_p = 3$ [$I_p < 4$]

Soil is SM

Hence the soil may designed as **SW.SM**