Birzeit University
Soil Mechanics, ENCE 331
Homework Assignment 1
(Due to 02 Nov 2023, 11:00 p.m.)

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1. Referring to Weight-Volume Relationships, for a given soil, show that:

   a. $\gamma_{sat} = \gamma_d + (\frac{e}{1+e})\gamma_w$

$V_s = 1$

$G_s = \frac{\gamma_s}{\gamma_w} = \frac{\frac{W_s}{V_s}}{\gamma_w} = \frac{W_s}{\gamma_w} \Rightarrow W_s = G_s \gamma_w$

$w\% = \frac{W_w}{W_s} = \frac{W_w}{G_s \gamma_w} \Rightarrow W_w = w G_s \gamma_w$

$\gamma_{sat} = \frac{W}{V} = \frac{W_w + W_s}{V} = \frac{w G_s \gamma_w + G_s \gamma_w}{e+1}$

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

but $e = w G_s$

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

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

   b. $\gamma_d = \frac{e S \gamma_w}{(1+e) w}$

$V_s = 1 \Rightarrow e = \frac{V_v}{V_s} \Rightarrow e = V_v$

$G_s = \frac{\gamma_s}{\gamma_w} = \frac{W_s}{V_s \gamma_w} = \frac{W_s}{\gamma_w} \Rightarrow W_s = G_s \gamma_w$

$w\% = \frac{W_w}{W_s} = \frac{W_w}{G_s \gamma_w} \Rightarrow W_w = w G_s \gamma_w$

$G_s = \frac{W_w}{w \gamma_w}$

$\gamma_d = \frac{W_s}{V} = \frac{G_s \gamma_w}{1+e}$

$= \frac{\frac{W_w}{w \gamma_w} \gamma_w}{1+e}$

$= \frac{W_w}{(1+e) w}$ But $S = \frac{V_w}{V_v}$

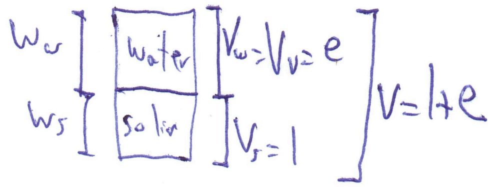
$S = \frac{W_w}{\gamma_w e}$

$W_w = S \gamma_w e$

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

$\gamma_d = \frac{e S \gamma_w}{(1+e) w}$ #

c. $e = \frac{\gamma_{sat} - \gamma_d}{\gamma_d - \gamma_{sat} + \gamma_w}$



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

$$\rightarrow \gamma_d (1+e) = G_s \gamma_w \quad \ldots\ldots (1)$$

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

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

$$\gamma_{sat}(1+e) - \gamma_w e = G_s \gamma_w \quad \ldots\ldots (2)$$

$$(1) = (2)$$

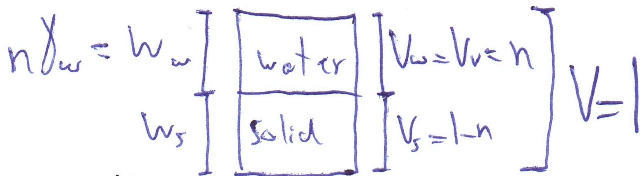
$$\gamma_d (1+e) = \gamma_{sat}(1+e) - \gamma_w e$$

$$\gamma_d + e\gamma_d - \gamma_{sat} - e\gamma_{sat} + e\gamma_w = 0$$

$$e(\gamma_d - \gamma_{sat} + \gamma_w) = \gamma_{sat} - \gamma_d$$

$$\boxed{e = \frac{\gamma_{sat} - \gamma_d}{\gamma_d - \gamma_{sat} + \gamma_w}} \quad \#$$

d. $w_{sat} = \frac{n\gamma_w}{\gamma_{sat} - n\gamma_w}$



$$G_s = \frac{\gamma_s}{\gamma_w} = \frac{W_s}{V_s \gamma_w} = \frac{W_s}{(1-n)\gamma_w}$$

$$\Rightarrow W_s = G_s \gamma_w (1-n)$$

$$W_w = n\gamma_w$$

$$\gamma_{sat} = \frac{W}{V} = \frac{W_w + W_s}{1} = n\gamma_w + (1-n) G_s \gamma_w$$

$$\gamma_{sat} = n\gamma_w + G_s \gamma_w (1-n)$$

$$\Rightarrow \gamma_{sat} - n\gamma_w = G_s \gamma_w (1-n)$$

$$w_{sat} = \frac{W_w}{W_s}$$

$$= \frac{n\gamma_w}{G_s \gamma_w (1-n)}$$

$$\boxed{w_{sat} = \frac{n\gamma_w}{\gamma_{sat} - n\gamma_w}} \quad \#$$

2. For a given soil, the moist unit weight is $17.8\ kN/m^3$ 17.8 kN/m3, the moisture content is 14%, and the specific gravity of the soil solids is 2.69, find the following:

$\gamma_w = 17.8\ \frac{kN}{m^3} \Rightarrow \gamma_w = \frac{W_w}{V} \Rightarrow 17.8 = \frac{W_w}{1}$

$W_w = 17.8\ KN$

$w = 14\% = 0.14$

$G_s = 2.69$

$\gamma_w = 9.81\ kN/m^3$

a. Dry unit weight

$W_s = ??$

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

$\frac{w}{1} = \frac{17.8 - W_s}{W_s}$

$0.14 W_s = 17.8 - W_s$

$W_s = 15.61\ kN$

b. Void ratio

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

$\gamma_d + \gamma_d e = G_s \gamma_w$

$\gamma_d e = G_s \gamma_w - \gamma_d$

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

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

$\Rightarrow$ but $\gamma_d = \frac{W_s}{V} = \frac{15.61}{1} = 15.61$

$e = \frac{2.69(9.81)}{15.61} - 1$

$e = 0.691$

c. Degree of saturation

$Se = wG_s$

$S = \frac{0.14(2.69)}{0.691}$

$S = 0.545 * 100\%$

$S = 54.5\ \%$

extra calculations:-

$G_s = \frac{\gamma_s}{\gamma_w} \Rightarrow \frac{2.69}{1} = \frac{\gamma_s}{9.81}$

$\gamma_s = 26.4\ kN/m^3$

$\gamma_s = \frac{W_s}{V_s} \Rightarrow 26.4 = \frac{15.61}{V_s}$

$V_s = 0.59\ m^3$

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

$V_w = 0.545(1 - 0.59)$

$V_w = 0.22\ m^3$

d. Various quantities of the phase diagram for unit volume of soil shown in **Fig. 1-1.**

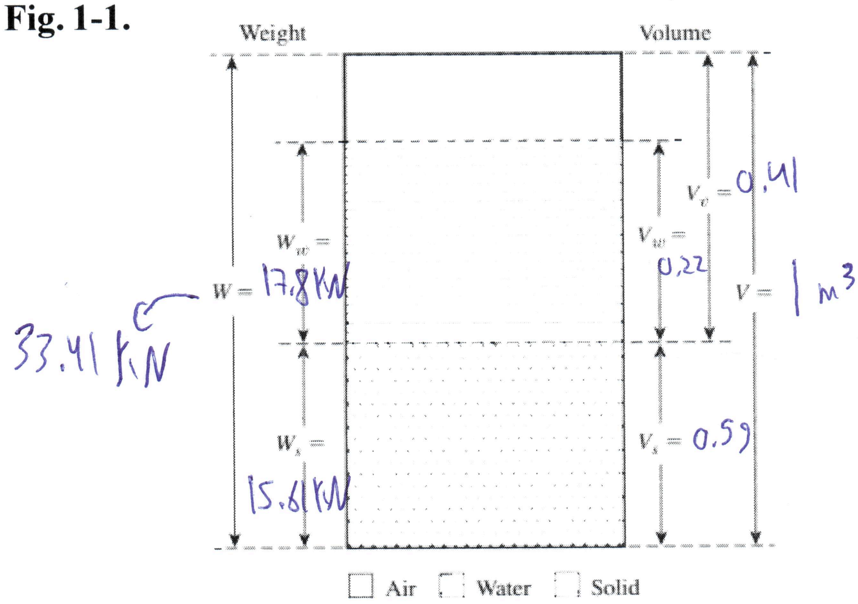


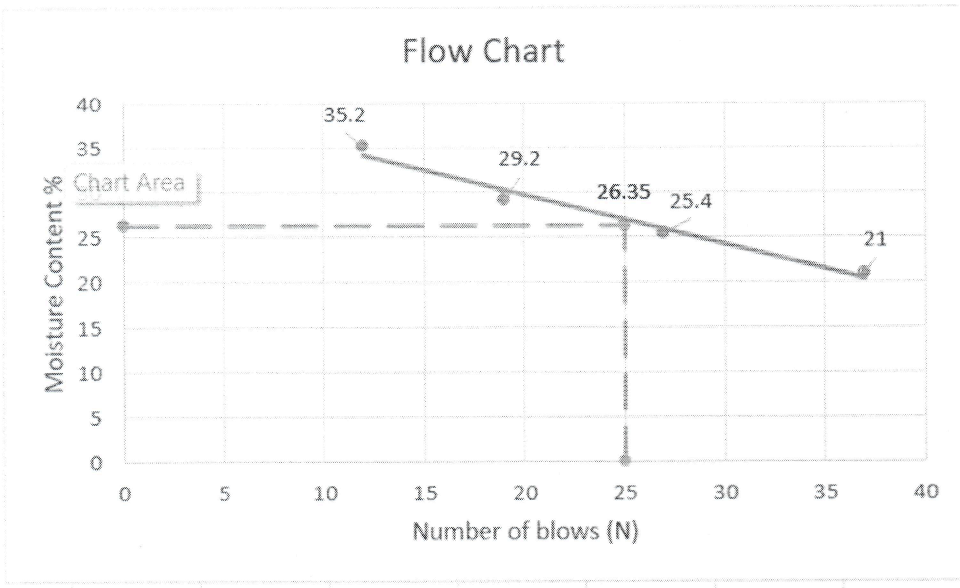
Fig. 1-1: Unit volume of soil element of three phases.

3. Liquid Limit test was conducted on a soil and the collected results are given below:

Number of blows N	Moisture content %
12	35.2
19	29.2
27	25.4
37	21

Determine:

a. Draw the flow curve.



b. Liquid Limit of the soil

L.L = 26.35% on the flow Chart

c. Plastic Limit of the soil if you know that PI = 6.5.

$PI = L.L - P.L$

$6.5 = 26.35 - P.L$

$P.L = 19.85\ \%$

d. Liquidity Index of the soil if $w_{in\ situ} = 23.8\%$.

$$LI = \frac{w - P.L}{L.L - P.L}$$

$$L.I = \frac{23.8 - 19.85}{26.35 - 19.85} = 0.607$$

4. Two saturated clay soil samples (sample I, and sample II) are subjected to the Shrinkage Limit test, find the Shrinkage Limit and the Shrinkage ratio of the given samples. The test results are given below:

Parameter	Volume cm^3	Mass g
$V_{i\,(I),(II)}$	19.3, 20.6	---
$V_{f\,(I),(II)}$	16, 13.8	---
$M_{1\,(I),(II)}$	---	37, 47.5
$M_{2\,(I),(II)}$	---	28, 34.6

For the First Sample (Sample I)

$V_i = 19.3\ cm^3$, $V_f = 16\ cm^3$ $\rho_w = 1\ g/cm^3$

$M_1 = 37\ g$, $M_2 = 28\ g$

$SL = w_i(\%) - \Delta w(\%)$

$= \left[\frac{M_1 - M_2}{M_2} * 100\right] - \left[\left(\frac{V_i - V_f}{M_2}\right) * \rho_w * 100\right]$

$= \left[\left(\frac{37 - 28}{28}\right) * 100\right] - \left[\left(\frac{19.3 - 16}{28}\right) * 1 * 100\right]$

$= 32.14 - 11.785 = 20.36\%$

$SR = \frac{M_2}{V_f \rho_w} = \frac{28}{16(1)} = 1.75$

For the Second Sample (Sample II)

$V_i = 20.6\ cm^3$, $V_f = 13.8\ cm^3$

$M_1 = 47.5\ g$, $M_2 = 34.6\ g$

$SL = \left[\left(\frac{47.5 - 34.6}{34.6}\right) * 100\right] - \left[\left(\frac{20.6 - 13.8}{34.6}\right) * 100\right]$

$= 37.28 - 19.65 = 17.63\%$

$SR = \frac{M_2}{V_f \rho_w}$

$= \frac{34.6}{13.8(1)}$

$SR = 2.51$

5. The sieve analysis of five soils and the liquid and plastic limits of the fraction passing through the No. 40 sieve are given below. Classify the soils by:

a. AASHTO classification system and give the group index for each soil.

b. Unified soil classification system, find the group symbols for the fine-grained soils.

Soil	Sieve Analysis- Percent Finer No. 10	No. 40	No. 200	Liquid Limit	Plasticity Index
1	98	80	50	38	29
2	100	92	80	56	23
3	100	88	65	37	22
4	85	55	45	28	20
5	92	75	62	43	28

a) All of the Soils have percent passing more than 35% that passes Through sieve # 200

Soil ① L.L = 38 ≤ 40 / PI = 29 ≥ 11

A-6 poor clayey Soil

$GI = (50-35)[0.2+0.005(38-40)] + 0.01(50-15)(29-10)$

$= 2.85 + 6.65 = 9.5 \approx 10$.

$\Rightarrow$ A-6 (10)

Soil ② L.L = 56 ≥ 41 / P.I = 23 ≥ 11 / 23 < 56-30

$\rightarrow$ A-7-5[a]

$GI = (80-35)[0.2+0.005(56-40)] + 0.01(80-15)(23-10)$

$= 12.6 + 8.45 = 21.05 \approx 21$

$\Rightarrow$ A-7-5[a] (21)

Soil ③ $L.L = 37 < 40$ / $PI = 22 > 11$

$\rightarrow$ A-6

$GI = (65-35)[0.2 + 0.005(37-40)] + 0.01(65-15)(22-10)$

$= 5.55 + 6 = 11.55 \simeq 12$

$\Rightarrow$ A-6 (12)

Soil ④ $L.L = 28 < 40$ / $PI = 20 > 11$

$\rightarrow$ A-6

$GI = (45-35)[0.2 + 0.005(28-40)] + 0.01(45-15)(20-10)$

$= 1.4 + 3 = 4.4 \simeq 4$

$\Rightarrow$ A-6 (4)

Soil ⑤ $L.L = 43 > 41$ / $PI = 28 > 11$ / $28 > (43-30)$

Percent passing from sieve #200 is 50 means the soil is fine-grained

$\rightarrow$ A-7-6[b]

$GI = (62-35)[0.2 + 0.005(43-40)] + 0.01(62-15)(28-10)$

$= 5.805 + 8.46 = 14.265 \simeq 14$

$\Rightarrow$ A-7-6[b] (14)

(b) Soil ① is not Accepted because it is above the ~~upper limit~~ U_line that means it is in the Upper limit

U_line $PI = 0.9(LL-8)$

$= 0.9(38-8) = 27 < 29$

Soil ②

percent passing from sieve #200 is $80 > 50$, so the soil is fine-grained soil

L.L = 51 / PI = 23

from the plasticity Chart the soil is inorganic silt with High compressibility or Organic silt (MH or OM)

Soil ③

Percent passing from Sieve #200 is $65 > 50$, so the soil is fine-grained soil

L.L = 37 / P.I = 22

From the plasticity Chart the soil is Inorganic or organic clay with Low plasticity (CL or OL)

Soil ④

Percent passing from sieve #200 is $45 < 50$, so the soil is Coarse-grained soil. There's no any retained in sieve #4. L.L = 28 / PI = 20

U-line $0.9(28-8) = 18 < 20$ it is in the Upper limit

S → sand

Soil ⑤

Percent passing from Sieve #200 is $62 > 50$, so the soil is fine-grained soil

L.L = 43 / PI = 28

From the plasticity Chart the soil is Inorganic or organic clay with Low plasticity