INS 3121
SOIL MECHANICS

Examples:
Weight–Volume Relationships and Plasticity

Assoc. Prof. Dr. Pelin ÖZENER
Civil Engineering Department
Geotechnics Division

Example 1

A cylindrical soil sample prepared for laboratory testing has a diameter of 71 mm, a height of 142 mm, and weighs 10.675 x 10^{-3} kN. If the degree of saturation is 93% and the specific gravity of soil solids is 2.71, determine:

a. void ratio

b. water content

c. water content under fully saturated condition

Solution 1

a. Given: $W = 10.675 \times 10^{-3} kN; S = 93\%;\ G_s = 2.71$

Specimen volume, $V = \frac{\pi}{4}(\frac{71}{1000})^2 \left(\frac{142}{1000}\right) = \mathbf{0.562 \times 10^{-3} m^3}$

$$\boldsymbol{W = W_W + W_S}$$

We know

$$\gamma_w = \frac{W_w}{V_w};\ G_s = \frac{W_s}{V_w \gamma_w}; S = \frac{V_w}{V_v}; and\ e = \frac{V_v}{V_s}$$

Therefore,

$$W = \gamma_w V_w + G_s V_S \gamma_w = \gamma_w S V_v + G_s V_s \gamma_w = \gamma_w S e V_s + G_s V_s \gamma_w$$

or

$$W = (Se + G_s)\gamma_w V_s$$

Solution 1

Since,

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

Substituting Vs, we get

$$W = \frac{\gamma_w V}{1 + e}(Se + G_s)$$

Substituting the known values,

$$10.675 \times 10^{-3} = \frac{(9.81)(0.572 \times 10^{-3})}{1 + e}(0.93e + 2.71)$$

Therefore,

$$\boldsymbol{e = 0.769}$$

Solution 1

b. $e + 1 = \frac{V_v + V_s}{V_s} \Rightarrow 0.769 + 1 = \frac{0.562 \times 10^{-3}}{V_s}$

Therefore, $\boldsymbol{V_s = 0.318 \times 10^{-3}\ m^3}$

And

$$W_s = G_s V_s \gamma_w = (2.71)(0.318 \times 10^{-3})(9.81) = \mathbf{8.454 \times 10^{-3}}\ \textbf{kN}$$

$$W_w = W - W_S = 10.675 \times 10^{-3} - 8.454 \times 10^{-3} = \boldsymbol{2.221 \times 10^{-3} kN}$$

Water content is given by

$$\omega = \frac{W_w}{W_s} = \frac{2.22.\times 10^{-3}}{8.454 \times 10^{-3}} = \boldsymbol{0.263\ or\ 26.3}\%$$

Solution 1

c. $V_v = V - V_s = 0.562 \times 10^{-3} - 0.318 \times 10^{-3} = 0.244 \times 10^{-3} m^3$

For saturated conditions, $\boldsymbol{V_w = V_v = 0.244 \times 10^{-3} m^3}$.

Therefore,

$$W_w(saturated) = \gamma_w V_w = (9.81)(0.244 \times 10^{-3}) = \mathbf{2.39 \times 10^{-3} kN}$$

$$W_w = \frac{W_w}{W_s} = \frac{2.39 \times 10^{-3}}{8.454 \times 10^{-3}} = \mathbf{0.283\ or\ 28.3\%}$$

Example 2

The mass of a moist soil sample collected from the field is 465 grams, and its oven dry mass is 405.76 grams. The specific gravity of the soil solids was determined in the laboratory to be 2.68. If the void ratio of the soil in the natural state is 0.83, find the following:

a. The moist density of the soil in the field (kg/m3)
b. The dry density of the soil in the field (kg/m3)
c. The mass of water, in kilograms, to be added per cubic meter of soil in the field for saturation

Solution 2

a. $\omega = \frac{M_w}{M_s} = \frac{465-405.76}{405.76} = \frac{59.24}{405.76} = \mathbf{14.6\%}$

From,

$$\rho = \frac{G_s \rho_w (1+\omega)}{1+e} = \frac{(2.68)(1000)(1.146)}{1.83} = \mathbf{1678.3\ kg/m^3}$$

b. From,

$$\rho_d = \frac{G_s \rho_w}{1+e} = \frac{(2.68)(1000)}{1.83} = \mathbf{1468.48\ kg/m^3}$$

c. Mass of water to be added = $\rho_{sat} - \rho$

$$\rho_{sat} = \frac{(G_s + e)\rho_w}{1+e} = \frac{(1000)(2.68+0.83)}{1.83} = \mathbf{1918\ kg/m^3}$$

So the mass of water to be added = $1918 - 1678.3 = \mathbf{239.7}\ kg/m^3$

Example 3

Results from liquid and plastic limit tests conducted on a soil are given:

a) Draw the flow curve and obtain the liquid limit.

b) What is the plasticity index of the soil.

c) Determine the liquidity index of the soil if $\omega_{in\ situ}$ 32%

d) Determine the type of fine-grained soil using plasticity chart

Liquid limit test	
Number of blows, N	**Moisture content (%)**
14	38.4
16	36.5
20	33.1
28	27.0
Plastic limit test	
PL	13.4

Solution 3

Flow curve for liquid limit determination

- Likit limit (LL) = **29%**
- Plasticity index (PI) = **29 – 13.4 = 15.6%**
- Liquidity index (LI) = $\frac{\mathbf{32-15.6}}{\mathbf{29-15.6}} = \mathbf{1.22 > 1}$

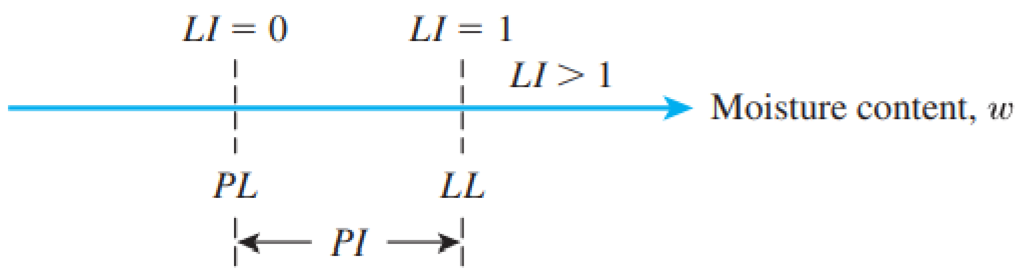
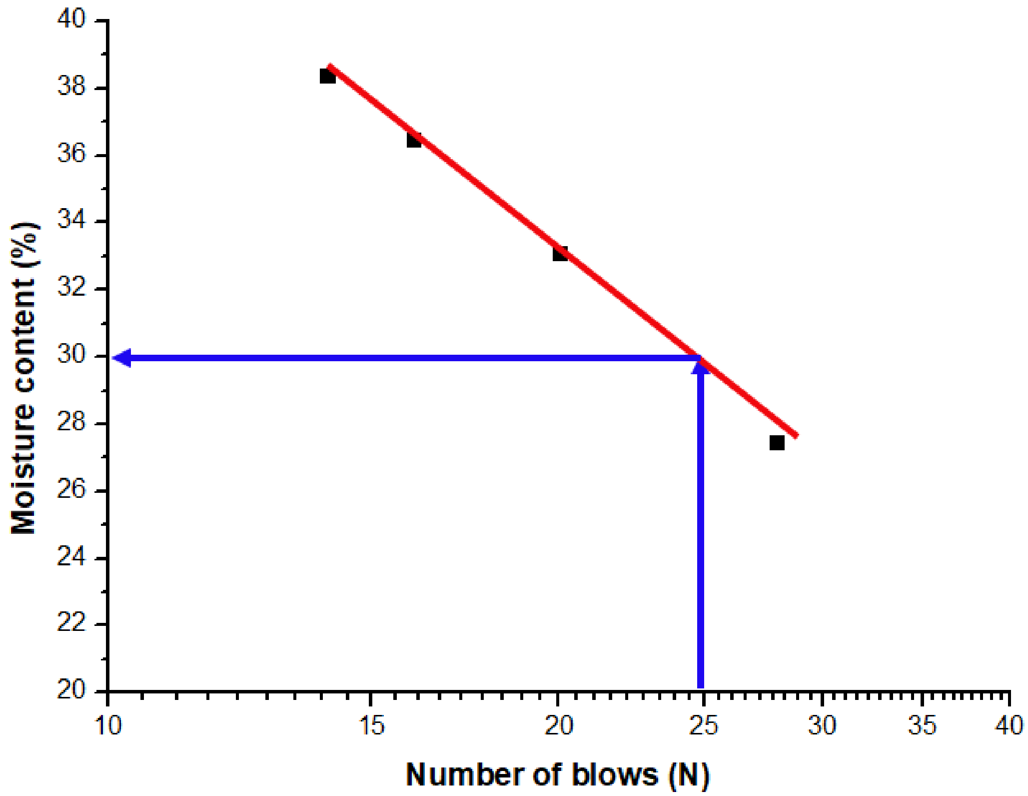


Figure 4.14 Liquidity index



Solution 3

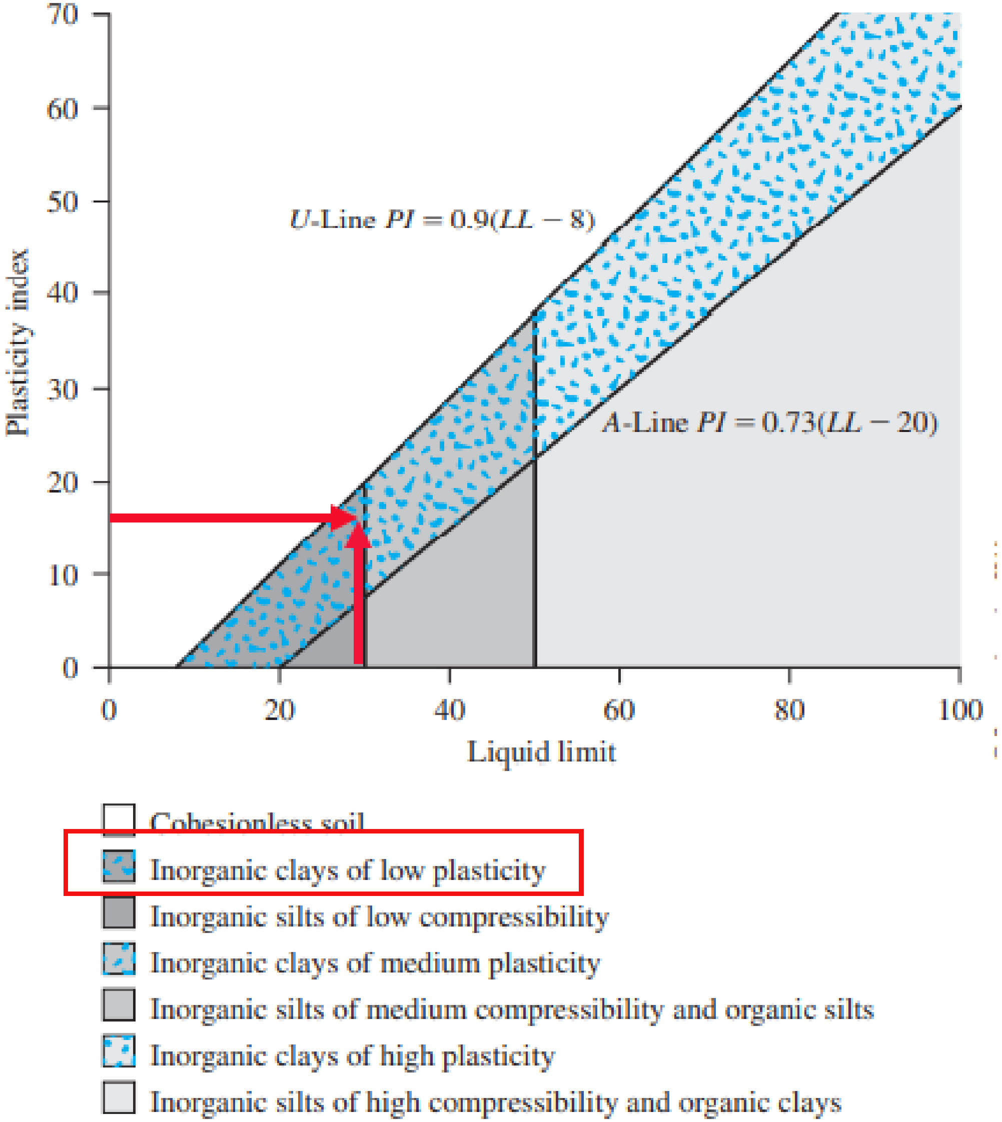


Figure 4.19 Plasticity chart