uOttawa
L'Université canadienne
Canada's university

CVG 3106 Winter – 2017
SOIL MECHANICS II

Assignment 1

(Due: 25 January, 2017 by 17:00)

Q1. For the soil profile shown in Figure 1 below:

a). calculate and plot the distribution of total stress, effective stress, and porewater pressure with depth. Neglect capillary action.

Calculate and plot the distributions of vertical effective and total stresses and porewater pressure with depth if the groundwater were:

b). to rise to the surface;

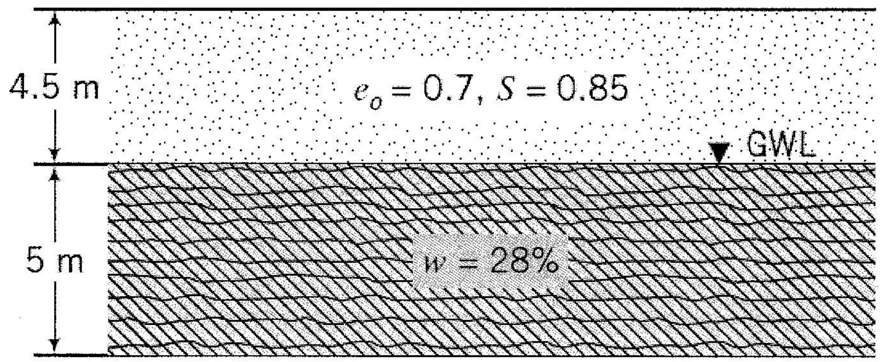


Figure 1

Solution:

a).

Unit weight of sand: Assume $G_s = 2.7$

$$\gamma = \left(\frac{G_s + Se}{1+e}\right)\gamma_w = \left(\frac{2.7 + 0.85 \times 0.7}{1+0.7}\right) \times 9.81 = 19.01\ kN/m^3$$

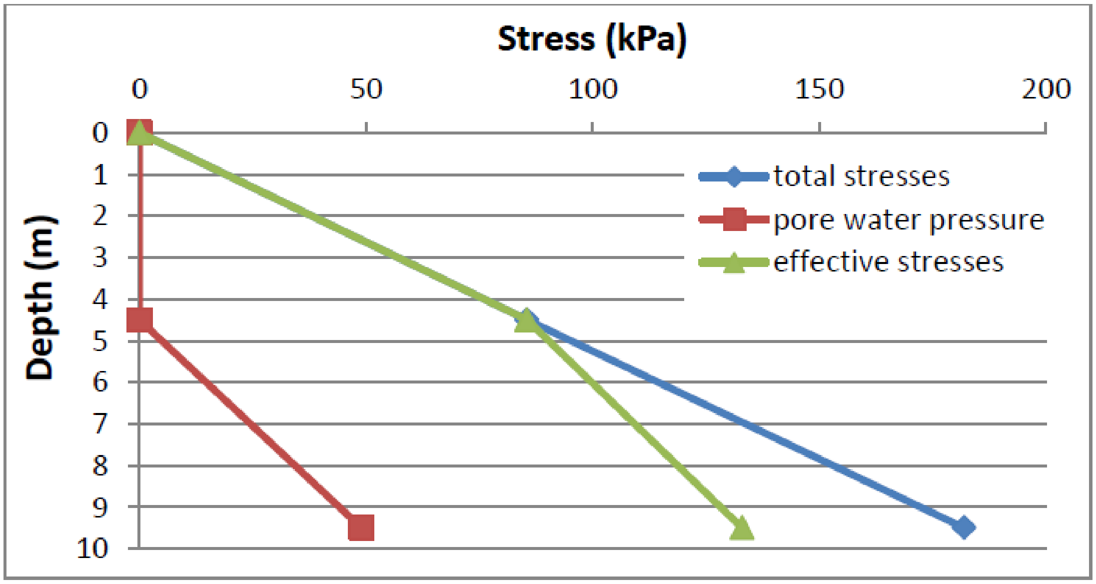
Clay layer:

Assume clay is fully saturated, $S=1$ (below GWT).

$$e = \frac{wG_s}{S} = \frac{0.28 \times 2.7}{1.0} = 0.756$$

$$\gamma_{sat} = \left(\frac{G_s + Se}{1+e}\right)\gamma_w = \left(\frac{2.7 + 1.0 \times 0.756}{1+0.756}\right) \times 9.81 = 19.31\ kN/m^3$$

Depth	σ (kPa)	u (kPa)	σ′ = (σ – u) (kPa)
0	0	0	0
4.5	19.01 × 4.5 = 85.55	0	85.55
9.5	85.55 + 5 × 19.31 = 182.10	5 × 9.81 = 49.05	133.05

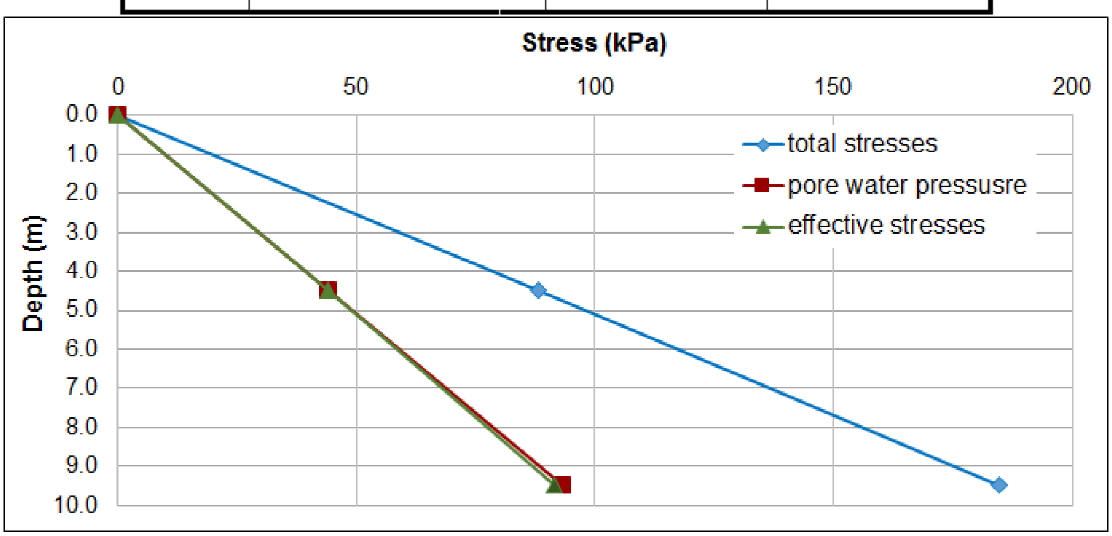


b)

Unit weight of saturated sand:

$$\gamma_{sat} = \left(\frac{G_s + Se}{1+e}\right)\gamma_w = \left(\frac{2.7 + 1.0 \times 0.7}{1 + 0.7}\right) \times 9.81 = 19.62 \text{ kN/m}^3$$

Depth (m)	σ (kPa)	u (kPa)	σ′ = σ –u (kPa)
0	0	0	0
4.5	19.62 × 4.5 = 88.29	4.5 × 9.81 = 44.15	44.15
9.5	88.29 + 5 × 19.31 = 184.84	9.5 × 9.81 = 93.20	91.65



Q2. An oedometer test on a saturated clay soil gave the following results: $C_c = 0.2$ and $C_s = 0.04$. The in-situ vertical effective stress in the field is 130 kPa. A building foundation will increase the vertical stress in the center of the clay by 150 kPa. The thickness of the clay layer is 2 m and its water content is 28%. Calculate the primary consolidation settlement of the clay layer in the field if:

a). OCR = 4.5;

b). OCR = 1.5.

Solution:

Initial thickness of the clay layer in the field:

$H = 2m = 2000\ mm$

$\sigma'_{z0} = 130\ kPa$ - in-situ vertical effective stress

$\Delta\sigma_z = \Delta\sigma'_z = 150\ kPa$ - stress increase

$\sigma'_{z1} = 130 + 150 = 280\ kPa$ - final vertical effective stress in the field.

a) OCR = 4.5

Calculate preconsolidation pressure, σ'_{zc}

$$OCR = \frac{\sigma'_{zc}}{\sigma'_{z0}} \rightarrow \sigma'_{zc} = OCR \times \sigma'_{z0}$$

$$\sigma'_{zc} = 4.5 \times 130 = 585\ kN/m^2 = 585\ kPa$$

$$\sigma'_{z0} = 130\ kPa < \sigma'_{z1} = 280\ kPa < \sigma'_{zc} = 585\ kPa$$

$\Rightarrow$ The clay is overconsolidated in the stress range σ'_{z0} to σ'_{z1}. Use C_s (not C_c)!

$$S_c = \frac{C_s}{1+e_0} H \log\left(\frac{\sigma'_{z1}}{\sigma'_{z0}}\right)$$

$S = 1.0$ fully saturated clay

Assume $G_s = 2.7$

$e_0 = w G_s = 0.28 \times 2.7 = 0.756$

$$S_c = \left(\frac{0.04}{1+0.756}\right) \times (2000) \log\left(\frac{280}{130}\right) = \underline{15.18\ mm}$$

b) OCR = 1.5

$\sigma'_{zc} = 1.5 \times 130 = 195\ kN/m^2 = 195\ kPa$

$\sigma'_{z0} = 130\ kPa < \sigma'_{zc} = 195\ kPa < \sigma'_{z1} = 280\ kPa$

The clay is overconsolidated in the stress range σ'_{z0} to σ'_{zc} (use C_s) and normally consolidated in the stress range σ'_{zc} to σ'_{z1} (use C_c).

$$S_c = \frac{C_s}{1+e_0} H \log\left(\frac{\sigma'_{zc}}{\sigma'_{z0}}\right) + \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_{z1}}{\sigma'_{zc}}\right)$$

$$S_c = \left(\frac{0.04}{1+0.756}\right)(2000)\log\left(\frac{195}{130}\right) + \left(\frac{0.2}{1+0.756}\right)(2000)\log\left(\frac{280}{195}\right) =$$

$$= \underline{43.81\ mm}$$

Q3. A sample of saturated clay, taken from a depth of 5 m, was tested in a conventional oedometer. The table below gives the vertical effective stress and the corresponding void ratio recorded during the test.

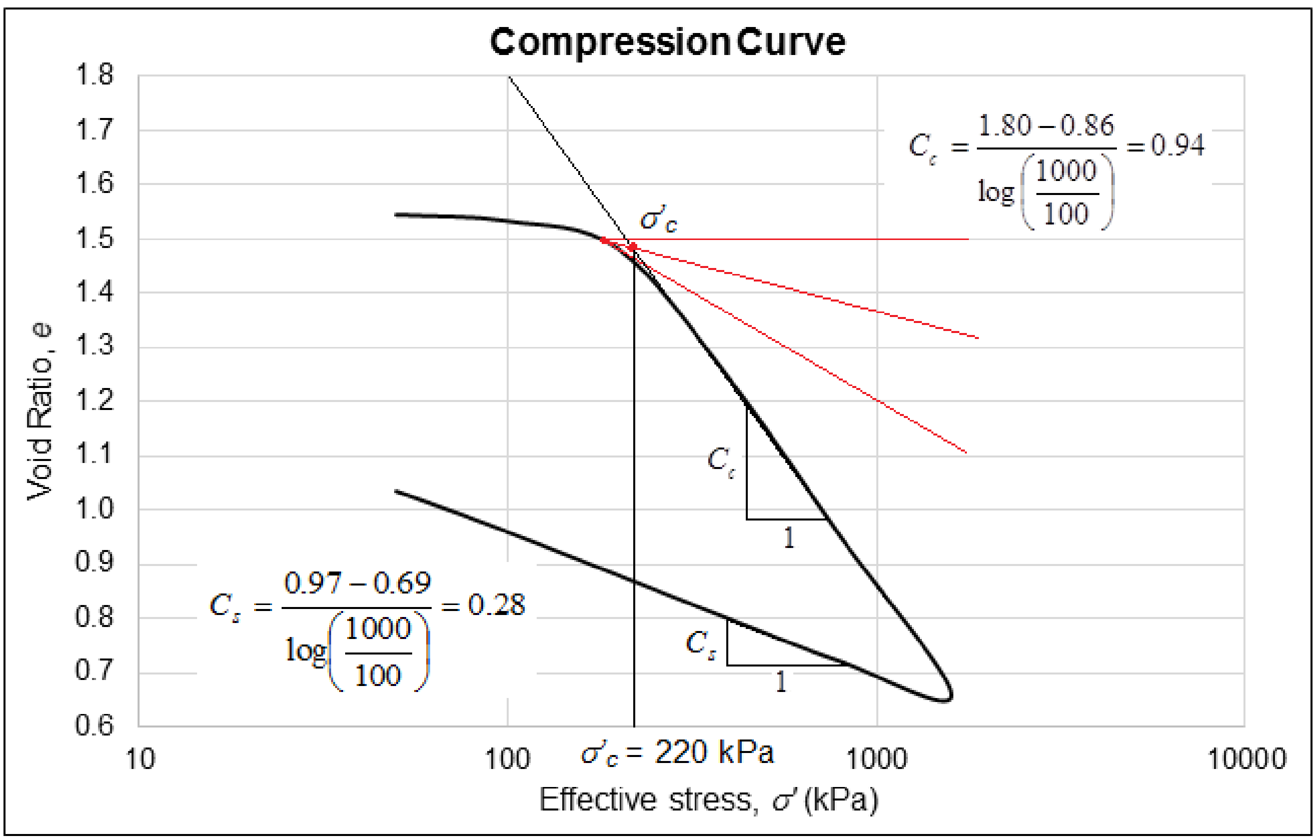
σ' (kPa)	50	100	200	400	800	1600	800	400	100	50
e	1.543	1.532	1.480	1.241	0.951	0.660	0.722	0.800	0.960	1.035

a). Plot a graph of void ratio versus log *σ'* (Compression curve).

b). Determine *Cc* and *Cs*. *Hint:* Use the rebound portion of the Compression curve to determine *Cs*.

c). Determine the preconsolidation pressure, σ'_c using Casagrande's method.

Solution:



Q4. A laboratory consolidation test on a 20-mm-thick sample of soil shows that 90% consolidation occurs in 30 minutes. Plot a degree of consolidation (U%) on the ordinate vs time (years) on the abscissa curve for a 10-m layer of this clay in the field for the drainage condition of:

a). single drainage;

b). double drainage.

Solution:

Lab consolidation test:

$H_o = 20\,mm = 0.02\,m$

$t_{90} = 30\,min = 30\,min / 60 \times 24 \times 365 = 5.71 \times 10^{-5}$ years

$H_{dr} = \frac{H_o}{2} = \frac{0.02}{2} = 0.01\,m$

For 90% consolidation $\rightarrow$ $T_v = 0.848$

$C_v = \frac{T_v H_{dr}^2}{t} = \frac{(0.848)(0.01)^2}{5.71 \times 10^{-5}} = 1.49\,m^2/year$

Field layer:

a) single drainage $H_o = H_{dr} = 10\,m$

b) double drainage $H_{dr} = \frac{H_o}{2} = \frac{10}{2} = 5\,m$

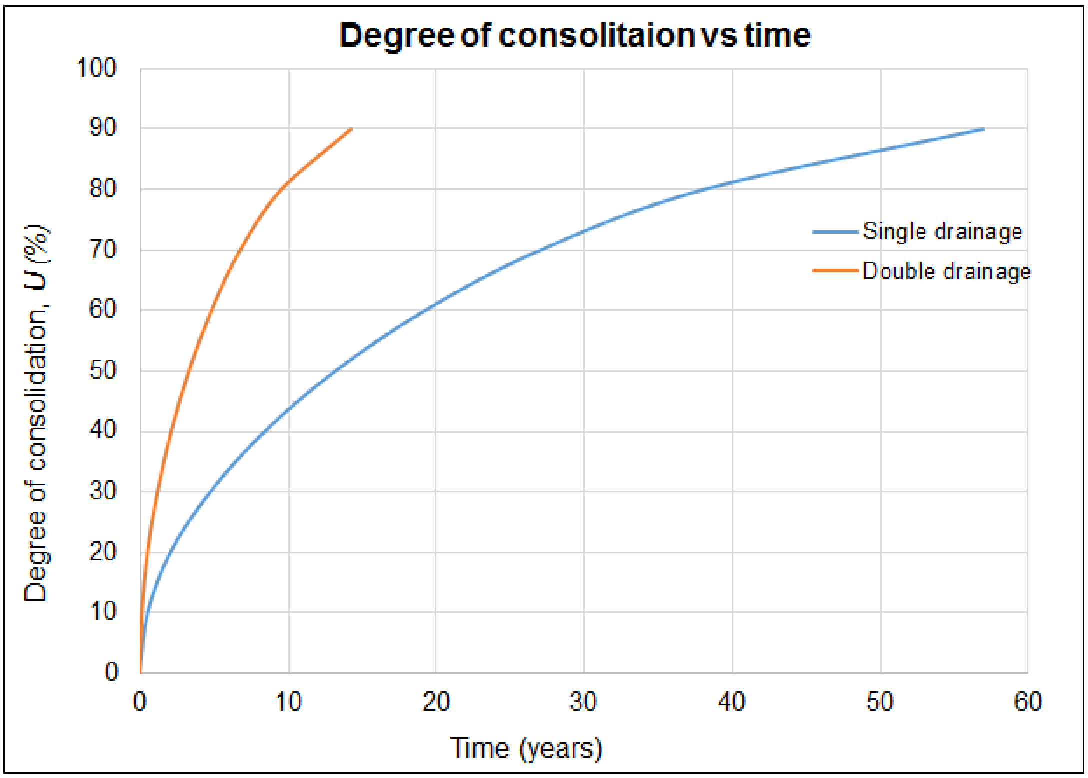
$C_v(field) = C_v(lab) = 1.49\,m^2/year$

$t(field) = \frac{T_v H_{dr}^2}{C_v}$

Set $U = 0, 10, 20 \ldots 90\%$ $\rightarrow$ obtain T_v (tables, charts)

Calculate $t(field)$ from above eq.

U (%)	Tv (-)	t (single dr.) (years)	t (double dr.) (years)
0	0	0.00	0.00
10	0.008	0.54	0.13
20	0.031	2.08	0.52
30	0.071	4.77	1.19
40	0.126	8.46	2.11
50	0.197	13.22	3.31
60	0.287	19.26	4.82
70	0.403	27.05	6.76
80	0.567	38.05	9.51
90	0.848	56.91	14.23



Q5. The failure stresses and excess porewater pressures for three samples of a loose sand in CU tests are given below.

Sample no.	$(\sigma_3)_f$ (kPa)	$(\sigma_1 - \sigma_3)_f$ (kPa)	Δu_f (kPa)
1	210	123	112
2	360	252	162
3	685	448	323

a). Plot Mohr's circles of effective stress at failure from these data for the three samples (same plot).

b). Determine the effective friction angle (ϕ') for the sand.

c). If the sand were to be subjected to a vertical effective stress of 300 kPa, what magnitude of horizontal effective stress would cause failure?

d). Determine the inclination of: (1) the failure plane, and (2) the plane of maximum shear stress to the horizontal.

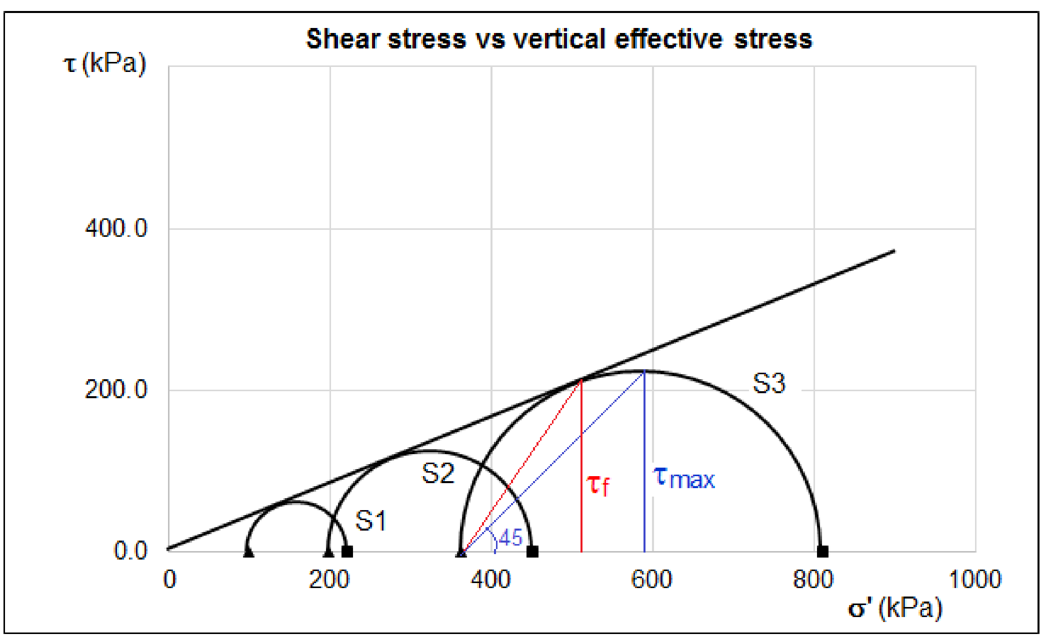
e). Determine the magnitude of the failure stresses for Sample 1.

f). Is the failure shear stress the maximum shear stress? Explain why or why not.

Solution:

a).

Sample # (-)	σ_3 (kPa)	$\sigma_1-\sigma_3$ (kPa)	Δu (kPa)	σ_1 (kPa)	σ_1' (kPa)	σ_3' (kPa)
1	210	123	112	333	221	98
2	360	252	162	612	450	198
3	685	448	323	1133	810	362



b) from graph
The effective friction angle for the sand is
$\phi' = \underline{22°}$

c) The vertical effective stress in the sand is the <u>major</u> principal effective stress (i.e, σ_1')
The principal stresses are related by:

$$\frac{\sigma_1'}{\sigma_3'} = \frac{1+\sin\phi'}{1-\sin\phi'} \quad (\text{for } c'=0 \text{ in sand})$$

$$\frac{\sigma_1'}{\sigma_3'} = \frac{1+\sin 22°}{1-\sin 22°} = 2.20$$

For $\sigma_1' = 300$ kPA

$$\sigma_3' = \frac{\sigma_1'}{2.20} = \frac{300}{2.20} = \underline{136.36 \text{ kPA}}$$

d) The inclination of the failure plane in a triaxial test is given by:

$$\theta = 45° + \frac{\phi'}{2} = 45° + \frac{22°}{2} = \underline{56°}$$

The maximum shear stress corresponds to the top of the Mohr circles: The plane of τ_{max} is inclined at an angle of <u>45°</u> to the horizontal.

e) From soil mechanics:

$$\tau_f = \frac{\sigma_1' - \sigma_3'}{2}\sin 2\theta$$

$$\sigma_f = \frac{\sigma_1' + \sigma_3'}{2} + \frac{\sigma_1' - \sigma_3'}{2}\cos 2\theta$$

For Test 1: $\theta = 56°$, $\sigma'_{1,f} = 221$ kPA, $\sigma'_{3,f} = 98$ kPA

$$\sigma'_f = \frac{221+98}{2} + \frac{221-98}{2}\cos(2\times 56°) = 136.46 \text{ kPA}$$

$$\tau_f = \frac{221-98}{2}\sin 2\theta = 57.02 \text{ kPA}$$

f) The maximum shear stress is not the failure stress. The failure shear stress is the ordinate of the point where the Mohr circle touches the Mohr-Coulomb failure envelope.