IMPERIAL COLLEGE L O N D O N

MEng EXAMINATION 2013

PART II

This paper is also taken for the relevant examination for the Associateship

CI 250: Soils and Engineering Geology

Wednesday 22nd May 2013: 14:00 - 17:00hrs

Answer all FIVE questions.
All questions carry equal marks.

Use separate answer books, one for Part A and the other for Part B.

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Take the unit weight of water, γ_w, as 9.8 kN/m^3.

PART A

Use a separate answer book for this part, answer all four questions.

1. a.) Draw a flow net to illustrate the pattern of flow into the excavation shown in Figure Q1. Indicate clearly the boundary conditions. The relevant soil properties are indicated on the figure.

(10 marks)

b.) What is the flow into the excavation per metre per day?

(3 marks)

c.) If the bulk unit weight of the soil is 21 kN/m^3 what is the vertical effective stress at point X?

(4 marks)

d.) What is the exit gradient adjacent to the sheet pile wall (i.e. the hydraulic gradient close to the base of the excavation) and suggest one practical way of reducing this value?

(3 marks)

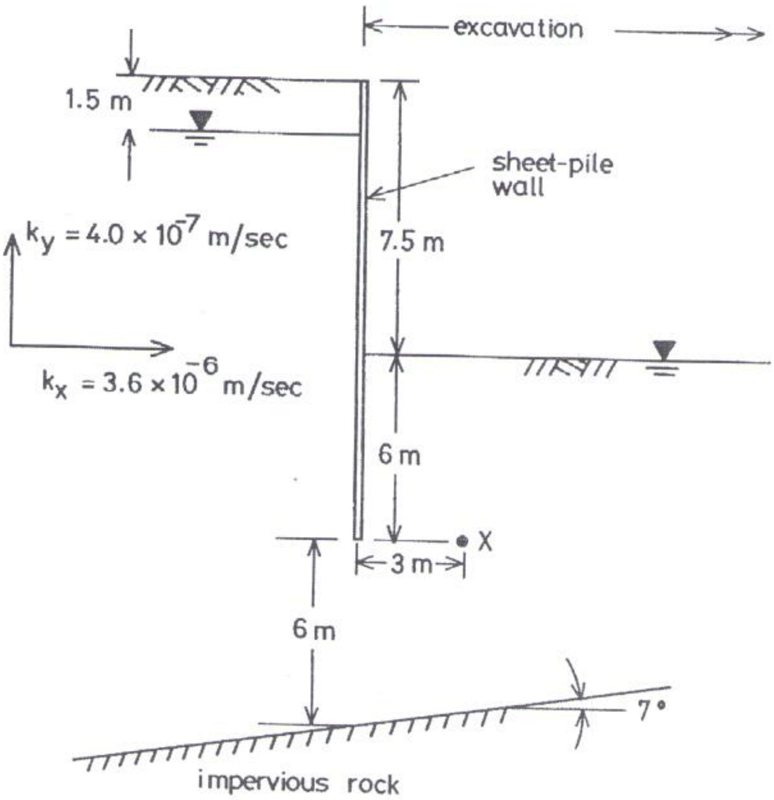
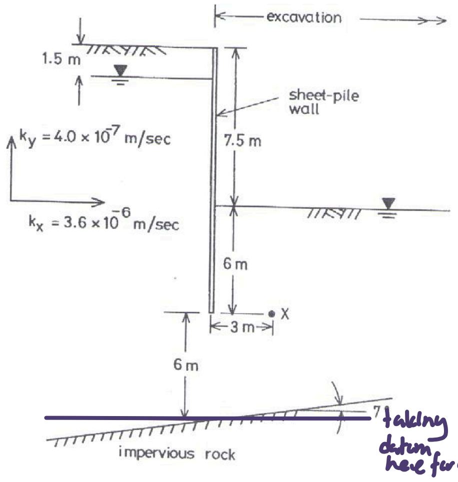
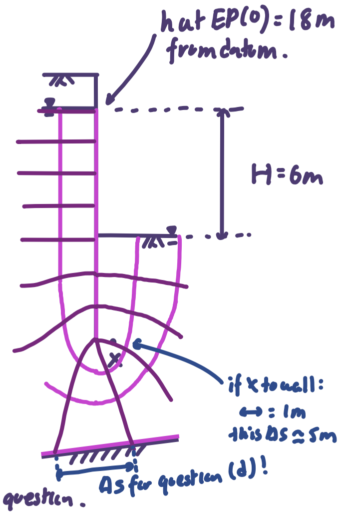


Figure Q1

Q1 (a) scaling factor of $x = \sqrt{\frac{k_y}{k_x}} = \sqrt{\frac{4.0\times10^{-7}}{3.6\times10^{-6}}} = \frac{1}{3}$





(b) $k = \sqrt{k_x k_y} = 1.2\times10^{-6}$ m/s

$$q = kH\frac{N_f}{N_d}$$

$$= 1.2\times10^{-6}\times 6\times\frac{3}{12}\times \underbrace{24\times60^2}_{m^2/s \rightarrow m^2/day}$$

$= 0.1552\, m^2/day/m$

(c) $\sigma = 21\times 6 = 126$ kPa

to find u:

we count how many drops from the first EP line.

no of drop = 8

$\Delta h = 6m$

head drop per EP $= \frac{6}{12} = 0.50$ m.

$h_x = 18 - 8\times0.50 = 14m$

$$h_x = \underbrace{z_x}_{\text{elev head}} + \underbrace{\frac{u_x}{\gamma_w}}_{\text{pressure head}}$$

$\frac{u_x}{\gamma_w} = 14m - 6m$

$u_x = 8\times9.8 = 78.4$ kPa

$\sigma' = 126kPa - 78.4kPa = 47.6kPa$

(d) $i = \frac{\Delta h}{\Delta s}$ Δh of one EP drop $= 0.50$ m.

$= \frac{0.50}{5}$

$= 0.10$

2.) The stratigraphy in an urban environment comprises 8 m of gravel, underlain by a 30m thickness of low permeability clay, which in turn overlies a considerable thickness of dense sand. The water table is within the gravel (the upper aquifer) at a depth of z = 2m below ground level. Water pressure in the dense sand (the lower aquifer) is artesian, such that the water level in a standpipe installed anywhere in this stratum stands at 5 m above ground level. The bulk unit weights of the strata are: gravel above water table $\gamma_s = 17.0$ kN/m³; gravel below water table $\gamma_s = 19.0$ kN/m³; clay, $\gamma_s = 21.0$ kN/m³; dense sand, $\gamma_s = 19.0$ kN/m³. In the following questions, state, and discuss if necessary, any assumptions you make.

a) Calculate the total vertical stress σ_v, effective vertical stress σ_v', and pore water pressure u at sufficient levels to draw profiles from the ground surface to depth z = 50 m (below ground level). Draw the profiles.

(8 marks)

b) Long-term pumping from the lower aquifer, to provide water for the urban area, reduces the water in the standpipe to a level corresponding to the base of the gravel, draw the steady state profiles of σ_v, u and σ_v' to $z = 50$ m.

(3 marks)

c) If samples taken from the mid-depth of the clay were found to have water contents of $w = 25.4\%$ initially and $w = 24.9\%$ in the long term after drawdown, calculate an average value of the volume compressibility m_v and the overall final settlement during drawdown. Take the specific gravity of the clay to be $G_s = 2.7$.

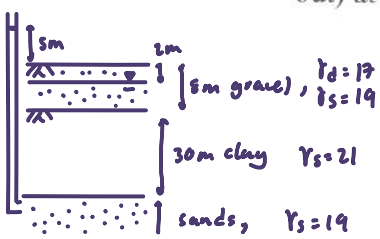
(6 marks)

long term.

d) A wide excavation has been made to a depth of z = 28 m below ground level *after* conditions have reached a steady state after drawdown. If pumping is stopped and the ground water pressure in the lower aquifer starts to increase again, at what level will water rise in the standpipe before there are problems of instability (blow out) at the base of the excavation?

(3 marks)

(a)



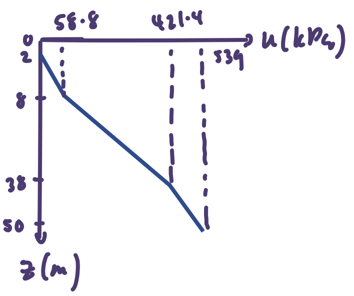
at z = 0m:
$\sigma = 0, u = 0, \sigma' = 0$

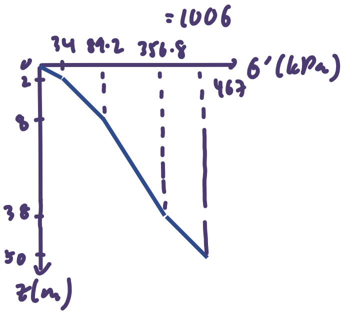
at z = 2m:
$\sigma = 17(2) = 34, u = 0, \sigma' = 34$ kPa

at z = 8m:
$\sigma = 17(2) + 19(6) = 148, u = 6(9.8) = 58.8, \sigma' = 89.2$ kPa

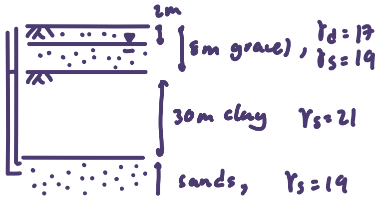
at z = 38m:
$\sigma = 17(2) + 19(6) + 21(30) = 778$ $u = 9.8(38+5) = 421.4$ $\sigma' = 356.6$ kPa

at z = 50m:
$\sigma = 17(2) + 19(6) + 21(30) + 19(12) = 1006$ $u = 9.8(50+5) = 539$ $\sigma' = 467$ kPa



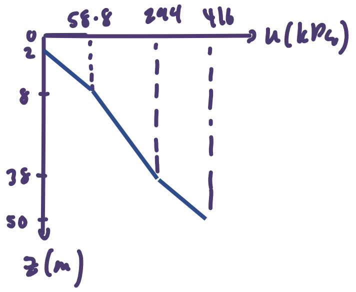


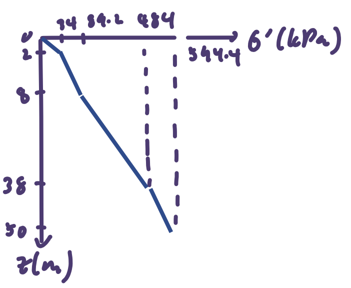
(b)



at z = 38m:
$\sigma = 17(2) + 19(6) + 21(30)$ $u = 9.8(30)$ $\sigma' = 484$ kPa
$= 778$ $= 294$

at z = 50m:
$\sigma = 17(2) + 19(6) + 21(30) + 19(12)$ $u = 9.8(50-8)$ $\sigma' = 594.4$ kPa.
$= 1006$ $= 411.6$





(c) aim: find m_v

method that we usually use: $m_v = \frac{1}{1+e_0}\left(\frac{\Delta e}{\Delta \sigma'}\right)$

2-ways to get u
1. interpolate graph:
$u_0 = \frac{58.8 + 421.4}{2} = 240.1$

2. find with linear extrapolate from z = 8.
$\Delta u = 7m$ $\frac{\Delta u}{\Delta s} = \frac{7}{30}$
$\Delta s = 30m$
$u_0 = \left[6 + 15 + 15\left(\frac{7}{30}\right)\right] \times 9.8$
$= 240.1$

$e = \frac{wG_s}{S_r}$ ($S_r = 1.0$)

$e = wG_s$

$e_0 = 0.254 \times 2.7 = 0.6858$
$e_1 = 0.249 \times 2.7 = 0.6723$

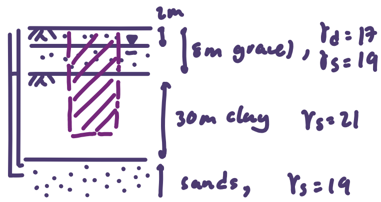
$\sigma_0' = \sigma_0 - u_0$
$= 17(2) + 19(6) + 21\left(\frac{30}{2}\right) - 240.1$
$= 222.9$ kPa

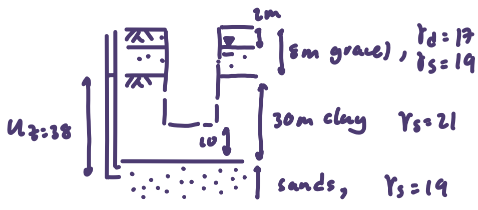
$\sigma_1' = \sigma_1 - u_1$
$= 17(2) + 19(6) + 21\left(\frac{30}{2}\right) - \frac{58.8 + 294}{2}$
$= 286.6$ kPa

$$m_v = \frac{1}{1+0.6858}\left(\frac{0.6858 - 0.6723}{286.6 - 222.9}\right) = 1.257 \times 10^{-4}\ m^2/kN$$

$\rho_\infty = m_v H \Delta\sigma'$
$= 1.257 \times 10^{-4}\ \cancel{m^2/kN} \times 30m \times (286.6 - 222.9)\ \cancel{kN/m^2}$
$= 0.2402$ m.

(d)





immediate: $\Delta u = \Delta\sigma$ (2019, q1b)
long term: calculate based on current situation (2013, q2d)

blow out: $u_{z=38} > \sigma_{z=38}$

$u_{z=38} = \sigma_{z=38}$
head $= \frac{21(10)}{9.8} = 21.43$ m

elevation level = 38 - 21.43 = 16.57 m.

3. Consolidated-undrained triaxial compression tests were carried out on three specimens of a clay, and the pore pressures, u, were measured during the tests. The stresses at failure of the three specimens were as follows.

Specimen no.	$\sigma_1 - \sigma_3$ (kPa)	σ_3 (kPa)	u (kPa)
1	54.8	70	27.4
2	94.0	110	37.0
3	141.4	170	60.4

a.) Determine the shear strength parameters c' and ϕ' for this clay and comment on the nature of the clay.

(8 marks)

b) If the normal total stress on a plane through the clay deposit is 112 kPa and the pore pressure is 58 kPa, what is the shear strength along that plane?

(3 marks)

c) What is the significance of the pole of planes with reference to a Mohr circle?

(2 marks)

d) What angle to the horizontal do you expect the failure plane in specimen no. 2 to form?

(2 marks)

e) Calculate the normal and shear stresses on the failure plane in specimen no. 2 in terms of effective stress.

(2 marks)

f) Give three advantages that the triaxial apparatus has compared with the shear box apparatus.

(3 marks)

main assumptions (stress field)

1. soil is at the point of failure everywhere.
2. equilibrium is satisfied locally.
3. failure criterion ($\tau = c' + \sigma_n' \tan\phi'$ or $\tau = S_u$) is satisfied at all points.

main assumption (limit equil.)

1. soil is at the point of failure only on a pre-defined surface.
2. equilibrium is satisfied globally

4. a) List main assumptions of the Stress Field method of analysis. What is the main difference between the Stress Field and Limit Equilibrium methods of analysis with respect to their assumptions?

(5 marks)

b) An embedded cantilever wall retains loose sand and penetrates 6m into the ground below dredge (excavation) level. A static water table exists at a depth 1m below dredge level. The wall penetrates through a layer of loose sand into dense sand. Assuming the front and the back of the wall are smooth and that loose and dense sand have properties indicated on Figure Q4, calculate the distribution with depth of Rankine active (σ_{ha}') and passive (σ_{hp}') horizontal effective stresses that act on the back and on the front of the wall respectively. Also calculate distributions of the corresponding pore pressures (u) and vertical effective stresses (σ_v'). Draw to scale appropriate diagrams of horizontal stress distributions with depth.

Note: calculate the above stresses at 0.0, 4.0, 5.0, 7.0 and 10.0m depth below ground surface. Consider that sand is dry above the ground water level and $\gamma_w = 9.8$ kN/m^3. You are reminded of the following expressions for active and passive horizontal stresses:

$$\sigma'_{ha} = \sigma'_v \cdot \tan^2(45^\circ - \phi'/2) - 2 \cdot c' \cdot \tan(45^\circ - \phi'/2)$$
$$\sigma'_{hp} = \sigma'_v \cdot \tan^2(45^\circ + \phi'/2) + 2 \cdot c' \cdot \tan(45^\circ + \phi'/2)$$

(15 marks)

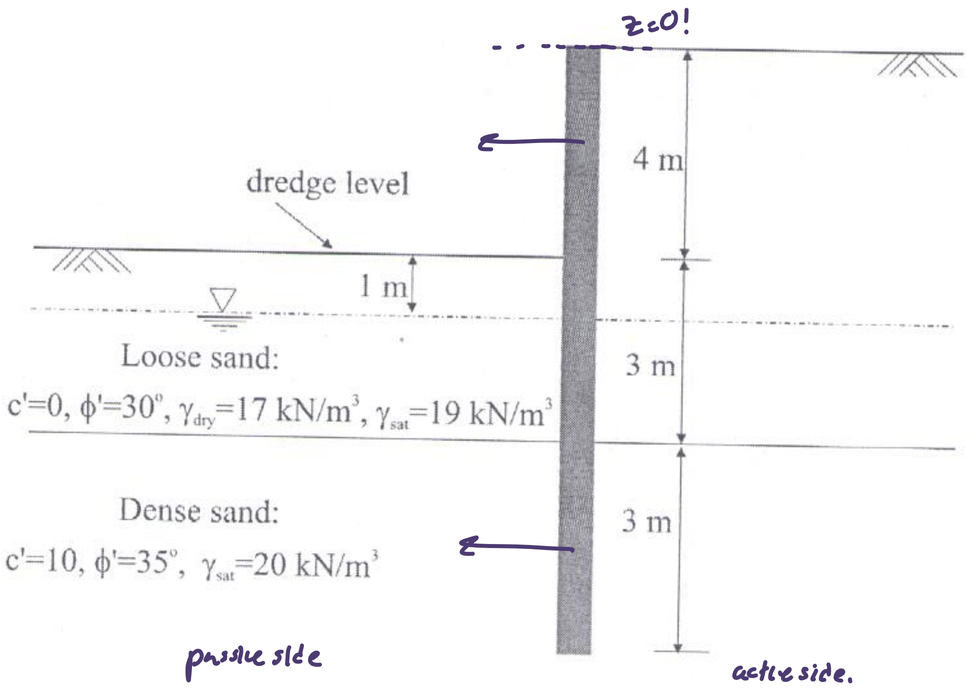


Figure Q4

Active side:

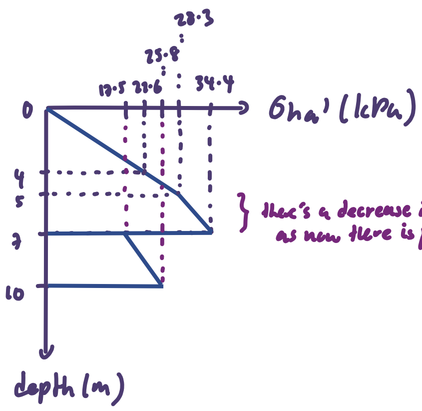
depth (m)	$\sigma_v' = \sigma - u$ (kPa)	$\sigma_{ha}' = \sigma_v' \tan^2(45 - \phi'/2) - 2c' \tan(45 - \phi'/2)$
0	0	0
4	$\sigma_v' = 4(17)$ $= 68$	$\sigma_{ha}' = 68 \tan^2(45 - 30/2)$ $= 22.67$
5	$\sigma_v' = 5(17)$ $= 85$	$\sigma_{ha}' = 85 \tan^2(45 - 30/2)$ $= 28.33$
7^-	$\sigma_v' = 5(17) + 2(19) - 2(9.8)$ $= 103.4$	$\sigma_{ha}' = 103.4 \tan^2(45 - 30/2)$ $= 34.47$
7^+	$\sigma_v' = 103.4$	$\sigma_{ha}' = 103.4 \tan^2(45 - 35/2) - 2(10) \tan(45 - 35/2)$ $= 17.61$
10	$\sigma_v' = 5(17) + 2(19) + 3(20) - 5(9.8)$ $= 134$	$\sigma_{ha}' = 134 \tan^2(45 - 35/2) - 2(10) \tan(45 - 35/2)$ $= 25.90$

at depth = 7m there's a change in failure condition. so have to find both.

... from marking scheme:

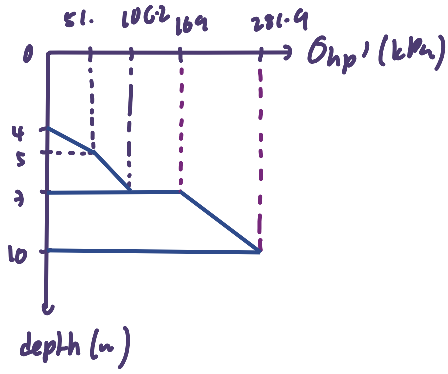
passive.

depth (m)	σ_{hp}' (kPa)
0	0
4	0
5	51.0
7^-	106.2
7^+	169.0
10	281.9



there's a decrease in the rate of increase as now there is pore water pressure.

steeper



PART B

Use a separate answer book for this part - make sure your annotated sheet is well attached.

5. a) From your recollection of your site visit and using the high-quality colour print as a guide, on the FAINT COPY highlight the main geological features and engineering issues that you can identify. You may divide and outline the image into units of similar materials and/or hazards (for example, the sky might be one unit) or use arrows to highlight any isolated or key features. Annotate fully; marks will not be awarded for outlines or features that are not clearly labelled.

(12 marks)

b) Discuss, in the form of a risk assessment, the natural hazards affecting the safety of the students sat or working under the cliff.

(8 marks)

Note: you are provided with a high-quality print and a faint copy for your answer.
DO NOT DRAW on the high-quality colour print; marks will not be awarded if you do.