IMPERIAL COLLEGE LONDON

MEng EXAMINATION 2018

PART II

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

CI2 - 250: Soils and Engineering Geology

Thursday 24th May 2018: 09:30 - 12:30hrs

Answer all FIVE questions.
All questions carry equal marks.

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

DO NOT OPEN THIS EXAMINATION PAPER UNTIL INSTRUCTED TO DO SO BY THE INVIGILATOR

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. In order to reduce the quantity of water flowing under the impervious dam shown in Figure Q1, two **alternative** schemes are to be considered. The first is a 90m long upstream impervious blanket, the second is a 20m deep impervious cut-off under the dam centre-line. Both are shown in Figure Q1. The soil beneath the dam has horizontal permeability $k_h = 4 \times 10^{-6}$ m/sec and vertical permeability $k_v = 6.4 \times 10^{-7}$ m/sec.

   a.) Establish, using the soil properties given above along with the dimensions and boundary conditions given in Figure Q1, which of the two schemes will be most effective in reducing the flow and show how you would calculate the flow rates.

   (12 marks)

   b.) Draw a graph to show the pore water pressures acting along the base of the dam in the two cases.

   (6 marks)

   c.) Comment briefly on which of the two schemes would be easier to construct and control?

   (2 marks)

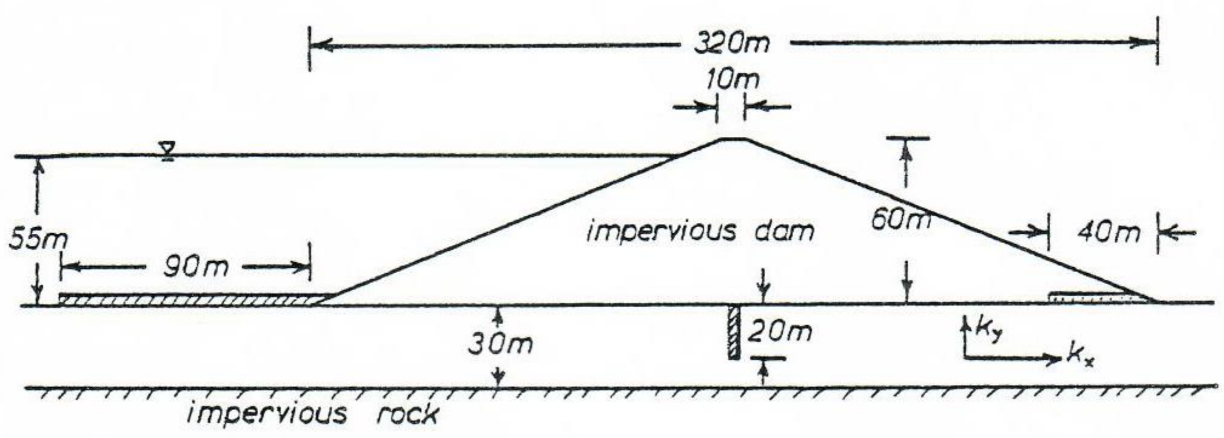

Figure Q1

q1 (a) scale x with $\sqrt{\frac{6.4\times10^{-7}}{4\times10^{-6}}} = 0.4$

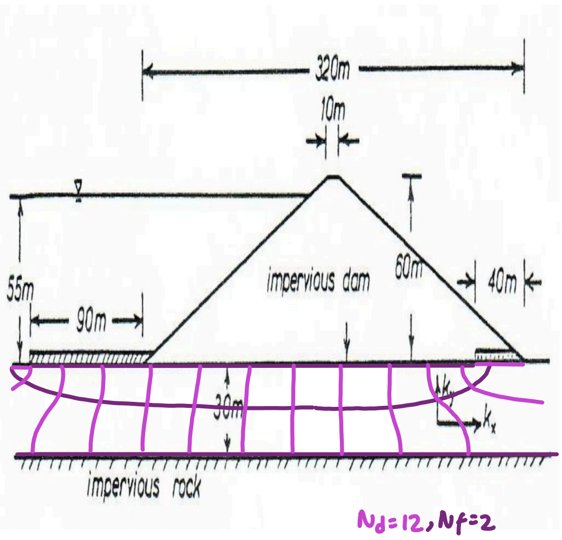

Figure Q1

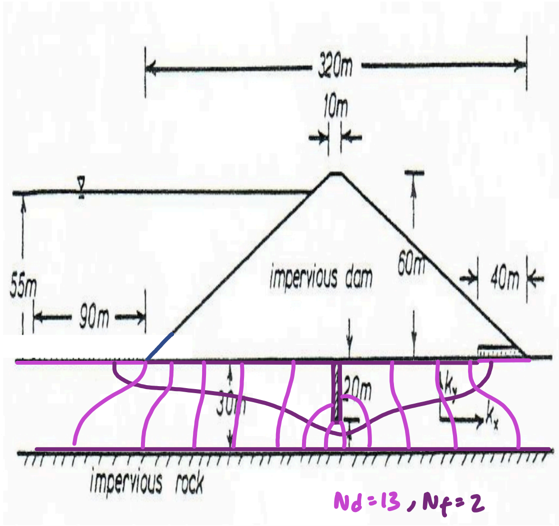

Figure Q1

$q = kH\frac{N_f}{N_d}$ the bigger the Nd, the smaller the q (more effective in reducing q!)

$\therefore$ case 2 is better

$k = \sqrt{k_x k_y} = 1.6\times10^{-6}$, $H = 55m$

$q_1 = 1.6\times10^{-6}\ ms^{-1} \times 55m \times \frac{2}{12}$

$= 1.467\times10^{-5} m^2s^{-1}$

$= 14.67\ mm^2s^{-1}$

$q_2 = 1.6\times10^{-6}\times 55 \times \frac{2}{13}$

$= 13.54\ mm^2s^{-1}$

(b) Δh (for across one EP)

$= \frac{H}{N_d}$

$\Delta h_1 = \frac{55m}{12} = 4.583m$ $\quad\Delta h_2 = \frac{55m}{13} = 4.231m.$

$h = \frac{u}{\gamma_w} + z$

since z at the base of the dam is constant (horizontal) put datum at there,

$z=0$: $h = \frac{u}{\gamma_w}$

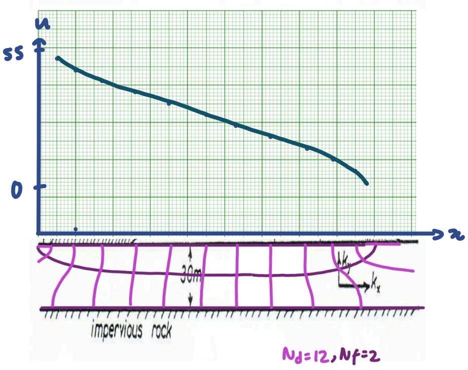

Figure Q1

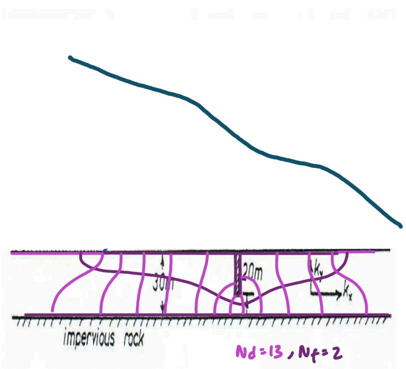

Figure Q1

2.

a.) Describe the mechanism of consolidation in a saturated clay.

(6 marks)

b.) In an oedometer test on a specimen of saturated clay, 75 mm in diameter, the applied pressure was increased from 100 to 200 kPa resulting in a change in thickness from 18.612 mm to 18.295 mm. The dry mass of the specimen, determined at the end of test sequence was 120.8 g and the value of G_s was 2.74. Determine the value of m_v for this loading stage (note that there are two ways in which this can be calculated, both give the same answer).

(6 marks)

c.) The clay tested in part (b.) came from a 5 m thick stratum with a free-draining 5 m thick sand layer above it and impermeable rock below it. A wide embankment is built on the ground surface such that the long-term average change in effective stress in the clay corresponds roughly to the stress increment considered in part (b.). What would the ultimate settlement be? How much of this would have occurred after 2 years if coefficient of consolidation for the same stress increment, c_v, was 1.575 m^2/year? The relationship between the average degree of consolidation and the dimensionless time factor, T_v are given in the table below.

(6 marks)

d.) Following from part (c.): it was discovered later that intense fracturing of the underlying rock had not been properly observed during the site investigation, in view of this what would the settlement be after 2 years?

(2 marks)

U	T_v
0.1	0.008
0.2	0.031
0.3	0.071
0.4	0.126
0.5	0.197
0.6	0.287
0.7	0.403
0.8	0.567
0.9	0.848
1.0	∞

3.

a.) Describe briefly, with the aid of a sketch, the triaxial apparatus and explain the steps involved in performing a consolidated undrained compression test.

(5 marks)

b.) With reference to testing in the triaxial apparatus, explain the following.

- What is the back pressure used for?
- How is the deviator stress (principal stress difference) determined?
- Why it is necessary to apply an area correction?

(3 marks)

c.) Consolidated undrained tests were performed on three samples of the same saturated clay. The results given in the table below were measured at failure in each test. Determine the values of the effective stress shear strength parameters c' and φ'.

Specimen no.	Cell pressure (kPa)	Deviator stress (kPa)	Pore water pressure (kPa)
1	100	200	16
2	200	357	32
3	400	560	128

(6 marks)

d.) What is the difference between a normally consolidated soil and an over-consolidated soil? Was the clay tested in part (c.) normally or over-consolidated and why? In view of your answer did the pore water pressures increase or decrease during shearing and why? Show schematically on a plot of effective stress versus void ratio, the likely position of the sample at the start and end of shearing in relation to the normal consolidation line and critical state line.

(6 marks)

4. The compacted granular fill shown in Figure Q4 is supported by a heavy, gravity-based retaining wall. The height of the wall is 3.5m. The base of the wall has suffered instability which has caused the wall to tilt back into the fill, promoting a planar failure surface 'cb', inclined at an angle, θ, of approximately 30° to the horizontal, as shown in Figure Q4. The effective cohesion in the granular fill is $c' = 0$ kPa, the angle of internal shearing resistance is $\phi' = 35^{\circ}$ and the bulk unit weight $\gamma = 20$ kN/m^3.

(a) Using the Limit Equilibrium method of analysis determine the magnitude of the horizontal force P that the wall exerts on the soil, and the magnitude of the reaction force R in the failure surface, as depicted in Figure Q4, assuming that the Mohr-Coulomb failure criterion is mobilised along the failure surface.

(Note: the line of action of R is at an angle ϕ' with respect to the direction normal to the failure surface; when writing force equilibrium equations, consider resolving all forces in the directions normal and parallel to the direction of R).

(10 marks)

(b) Assess the proximity of the conditions in the fill to the conditions corresponding to passive failure in the soil. You are reminded that, for the passive failure behind the wall, the inclination of the failure surface to the horizontal should be at $\theta_p = \pi/4 - \phi'/2$, and that the passive earth pressure coefficient $K_p = (1 + \sin\phi')/(1 - \sin\phi')$.

(Hint: calculate the magnitude of the horizontal passive force, P_p, from the passive horizontal effective stresses, σ'_{hp}, acting at the back of the wall, if $\sigma'_{hp} = K_p \cdot \sigma'_v$, with $\sigma_v{}'$ being the vertical effective stress behind the wall; for assessment compare the magnitudes of P and θ currently in the slope against P_p and θ_p).

(10 marks)

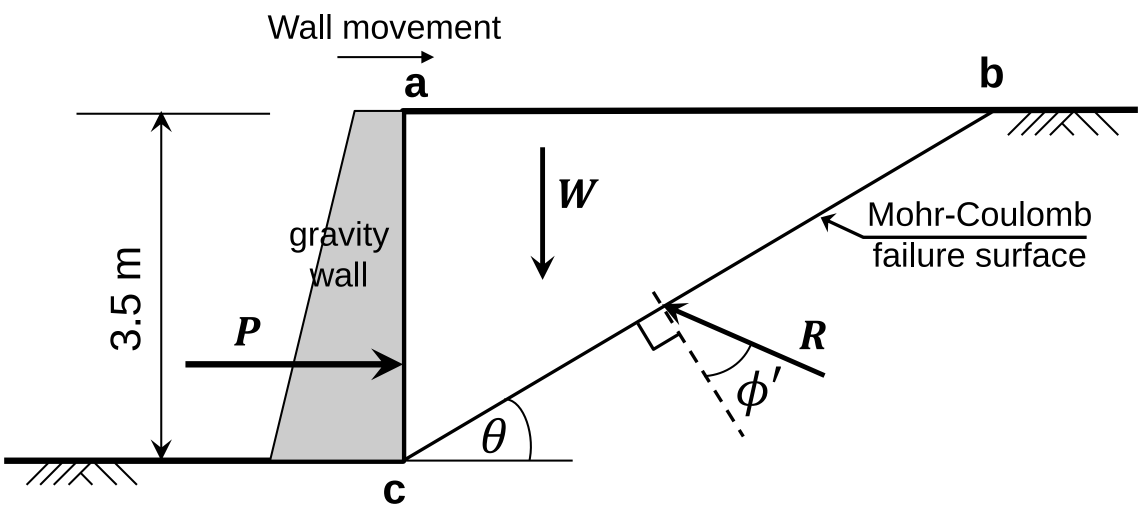

Figure Q4

PART B

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

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

   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. Divide and outline the image into units of similar materials and/or hazards (for example, the sky might be one unit). 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. The stereonet in Figure Q5 below shows a kinematic analysis of the southern slope of the quarry at Burrington Coombe, the poles plotted on the stereonet represent the bedding at the site. Label the diagram correctly using the labels provided below:

   Friction Cone
   Primitive Circle
   Great circle of slope face
   Daylight envelope of slope face
   Lateral limits for planar failure

   Using the stereonet is planar or toppling failure possibly on this slope? Briefly explain your answer.

   (8 marks)

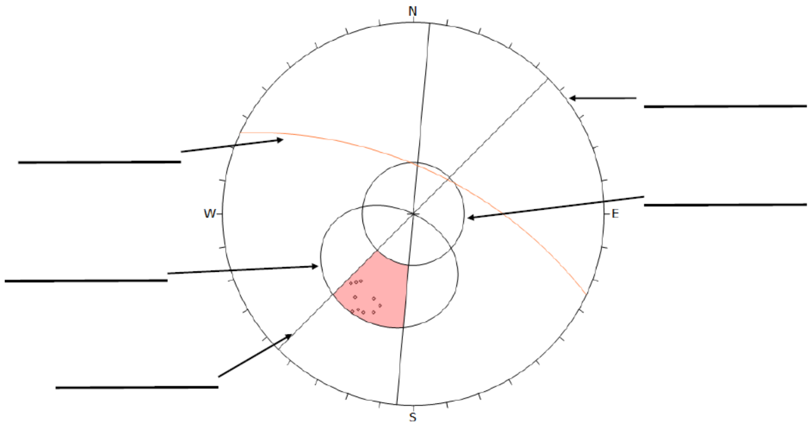

Figure Q5